AERONAUTICS
IN THE UNITED STATES
1918

GEORGE OWEN SQUIER

AERONAUTICS IN THE UNITED STATES

AT THE SIGNING OF THE ARMISTICE

NOVEMBER 11, 1918

An Address before the American
Institute of Electrical Engineers

BY

GEORGE OWEN SQUIER, Ph. D.

Major General, Chief Signal Officer, United States Army
Fellow of the Physical Society of London
Member of the Royal Institution of Great Britain
Member of the National Research Council
Member of the American Physical Society
Member of the American Institute of
Electrical Engineers etc.

CONTENTS.

ILLUSTRATIONS

Presented at the 345th Meeting of the American Institute of Electrical Engineers, New York, January 10, 1919.

AERONAUTICS IN THE UNITED STATES, 1918

BY GEORGE O. SQUIER

Abstract of Paper

Major General George O. Squier, Chief Signal Officer of the United States Army, reviews in this address the development of Military Aeronautics in the United States up to the date of the armistice, November 11, 1918. The War Department's first heavier-than-air flying machine was produced approximately ten years ago, but for the eight years that followed, the development lagged—in fact less than a million dollars was appropriated for aeronautics in the entire eight years. Then under the pressure of war, the United States by necessity plunged into a gigantic aircraft program—and the accomplishments today are numbered by the score. The Liberty Engine, acknowledged now to be the standard for the world, was produced; an industry new to the United States was developed, and other tremendous strides taken in the science of aerial navigation.

I—Introduction

ALMOST exactly ten years ago (December, 1908) the undersigned had the honor of addressing, from this same platform, the American Society of Mechanical Engineers on the subject of Military Aeronautics, at its annual meeting. The preceding summer months had witnessed the first public flights of the Wright airplane at Fort Myer, Virginia.

The Signal Corps of the United States Army, under date of December 23, 1907, had issued an advertisement and specification for a heavier-than-air flying machine, and the sealed proposals under this specification were opened formally at Washington at twelve o'clock noon on February 1, 1908. The main requirement before acceptance, by the Government, was an endurance test in which the flying machine must remain continuously in the air for one hour without landing.

We all remember the world-wide interest which was aroused by the performance of this new and promising realization of the dream of the ages. During the continuance of the experiments, the eyes of the world were centered upon the little flying field just outside of Washington. The President and Cabinet Ministers were in frequent attendance, and the Congress adjourned from day to day whenever a flight was in prospect.

And then an almost inconceivable thing occurred. The Messrs. Wright having thoroughly demonstrated and fulfilled all of the conditions required by that specification, and the first machine having been duly purchased and paid for, during the eight years following the entire appropriations by this government for military aeronautics amounted to less than a million dollars.

European Powers, however, in their quest for military advantage, quickly interpreted what had happened at Fort Myer, and France, in particular, during these years was responsible for the principal advances in construction and design.

I shall not enter here into the causes, some military, some civil, of this utter unpreparedness, but the outbreak of war found the United States with but a handful of fliers and very few training planes. There was no aviation industry in this country, and the number of professional men trained as aeronautical engineers and designers was so small as to be practically negligible. In this respect the problem of developing the air program was unique. The United States had built ships before, had manufactured clothing, guns, munitions, built cantonments, etc.; and had a splendid body of men trained in these professions and employments, but, outside of a few men there was no one in the United States with experience in the design or building of even training planes.

Once the United States actually had entered the war, the pressure from our Allies and a sudden realization of our real situation in aeronautics led Congress to grant for this purpose, in the Act of May 12, 1917, $10,800,000; the Act of June 15, 1917, $31,846,000, and finally the appropriation of $640,000,000, the largest ever made by Congress for one specific purpose, which was put through the House of Representatives' Military Affairs Committee in two sittings, the House itself in one, the Senate Military Affairs Committee in forty-five minutes; and the Senate itself a week later, becoming a law on July 24, 1917, three months and a half after the outbreak of war.

The task you have given me of presenting within the present hour even an outline of the great undertaking which this nation has accomplished during the last nineteen months in developing the Air Service, is indeed impossible to meet.

I hasten to say at the outset that I can only hope to present to you some of the salient features and accomplishments of this effort. Of the hundreds and thousands of men and women

who wrought valiantly and loyally to achieve these results, it will be impossible to mention specific names, or to give anything like just credit or mention to individuals or particular corporations.

Where names are mentioned in connection with certain features of the work, it must not be interpreted that there are not many others who are equally meritorious.

The Honor Roll of this Institute comprises no less than 1,317 men who participated in the Allied forces in the Great War. Of these, 976 were officers, 728 were officers in the American Army, 110 in the Signal Corps, and 52 in the Air Service.

Indeed, it is only in the long reaches of future history that we can form a just estimate of the many lines of endeavor which were set in motion in carrying out this enterprise, and which will, it is hoped, go forward into the future to bear their fruits in times of peace.

II—Statistical Résumé of Aircraft Production and Training

THE work involved in training aviators and obtaining aeronautical equipment in the United States has been of such magnitude as to preclude the possibility of presenting here anything more than a brief résumé of the major accomplishments.

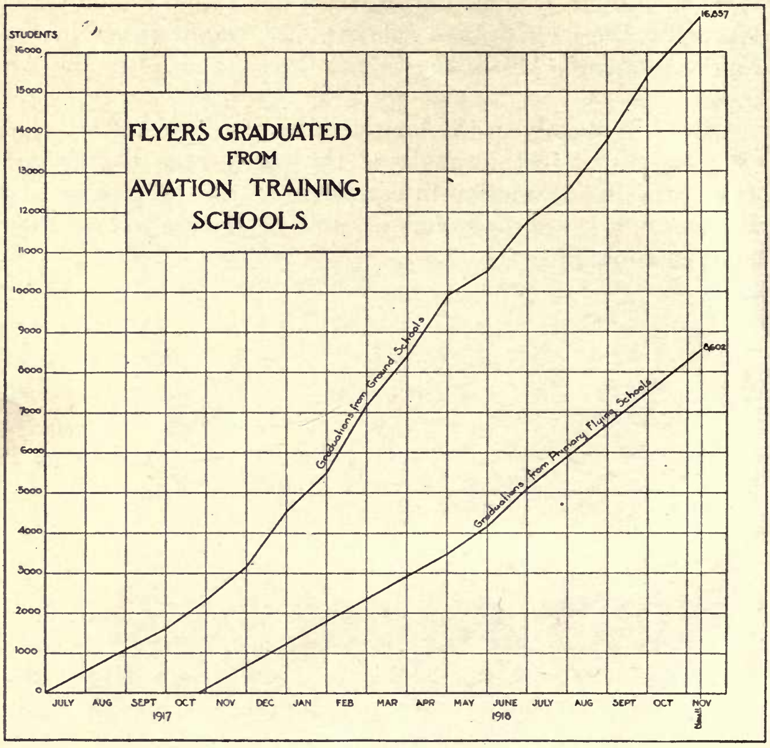


FIG. 1

The data is presented as of six o'clock a.m., November 11, 1918 (the date of the signing of the armistice).

PERSONNEL

More than 8600 fliers have been trained in the United States since its entry into the war. Monthly graduations from ground and flying schools are shown on Fig. 1. The gradually increasing deviation between the two curves on this chart is caused largely by failure of graduates of ground schools to develop into fliers.

There have been training fatalities in the United States, as in all other countries where training has been conducted on a large scale. However, when the fact is realized that our students have flown more than 880,000 hours, which is the equivalent to more than 66,000,000 miles, it will be seen that our training casualties have been astonishingly few. Statistics show that the United States has a lower percentage of fatalities than any other of the allied countries. The monthly average in the United States has been only one fatality for each 3200 hours flown. Training fatalities by months are shown in Fig. 2, and in Fig. 3 are shown the analyzed causes of these fatalities. Two independent investigations made in connection with this paper have developed the fact that more than 90 per cent of training casualties are attributed to the aviator himself. Fig. 4 shows the actual distribution of our fliers overseas.

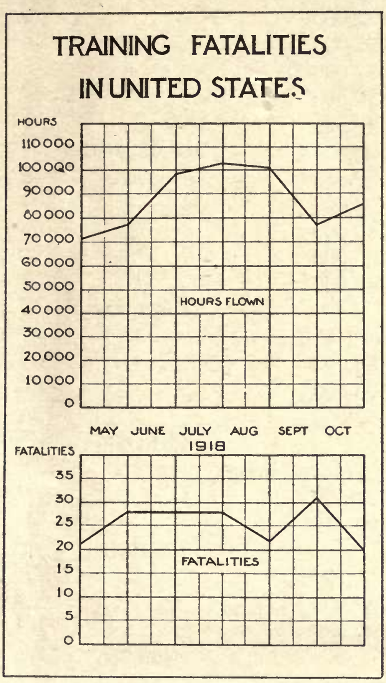


FIG. 2

TRAINING EQUIPMENT

Herewith is presented a tabulation showing the actual production of training material up to November 11, 1918:

Planes		Engines			Propellers
Type	Number			Number	Number
Elementary	furnished	Name	H.P.	furnished	furnished
JN–4D	3,762	OX–5		83,18	17,830
SJ–1	1,600	A–7–A		2,250	5,173
Advanced					
JN–4H	929				
JN–6H	803	Hispano	150	3,497	5,295
SE–5	6				
S–4B	100	Gnome	100	278	500
S–4C	384				
E–1	18	La Rhone	80	1,107	358
Total	7,602			15,450	29,156

Raw Materials

Some idea of the quantity of wood necessary for airplane and propeller construction may be obtained from the following table of actual deliveries:

	Spruce Board Feet	Totals
U. S. Army	25,472,000	
U. S. Navy	8,667,000	
England	36,877,000	
France	22,929,000	
Italy	9,147,000	
		103,092,000
	Douglas Fir	
U. S. Army	19,193,000	
U. S. Navy	21,746,000	
England	21,226,000	
France	9,460,000	
		71,625,000
	Port Orford Cedar	
U. S. Army	30,000	
U. S. Navy	1,926,000	
England	2,557,000	
		4,513,000
	Mahogany, Central American	
U. S. Army & Navy	4,524,000	
Allies	4,197,815	
		8,721,815
	Mahogany, African	
U. S. Army & Navy	269,000	
Allies	200,935	
		469,935
	American Black Walnut	
U. S. Army & Navy	2,408,000	
Allies	2,096,876	
		4,504,876
	Quartered White Oak	
U. S. Army & Navy	308,000	308,000
	Cherry	
U. S. Army & Navy	618,000	618,000
	Ash	
U. S. Army & Navy	87,000	
Allies	33,565	
		120,565
	Birch	
U. S. Army & Navy	663,000	663,000

In addition to airplane wood, it was found necessary to maintain strict supervision over the production of airplanes and balloon fabrics. Of this class of material there had been

produced to November 11, 1918, 3,187,000 yards of linen; 7,000,000 yards of cotton airplane fabric; 2,647,000 yards of balloon fabric.

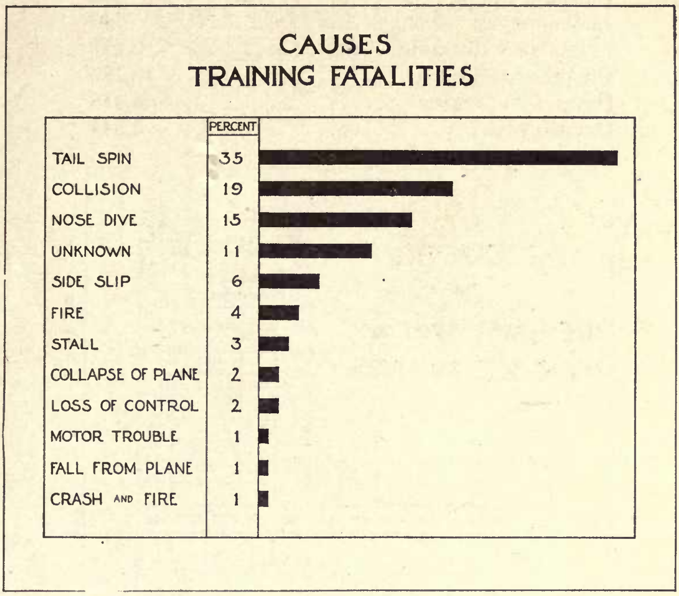


FIG. 3

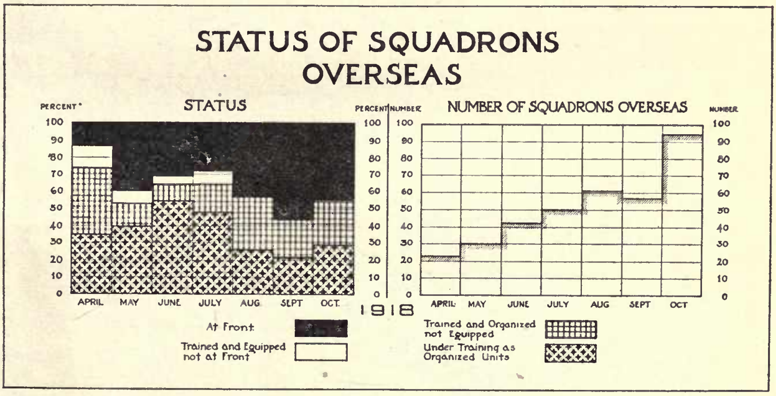


FIG. 4

ACCESSORIES

The production of airplane accessories to November 11, 1918 was as follows:

Air Pressure Gages	9,994
Air Speed Indicators	9,051
Altimeters	19,657

Clocks	17,593
Compasses Type "B"	10,179
Fire Extinguishers	12,209
Gasoline Gages	550
Inclinometers	40
Map Cases Rotating	2,417
Oil Pressure Gages	12,187
Oxygen Apparatus	4,318
Oxygen Masks	3,341

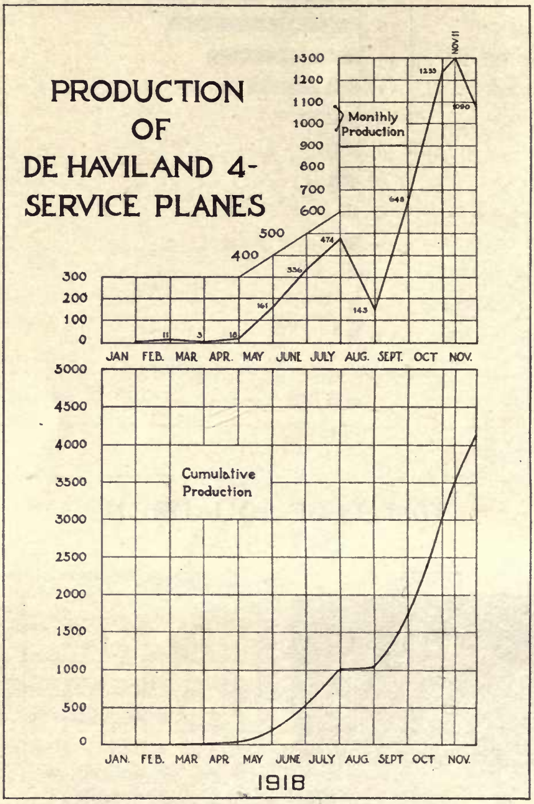


FIG. 5

Oxygen Tanks	12,000
Panels Switch	15,466
Radiator Thermometers	11,984
Tachometers	20,549

Ordnance for use in connection with the air service, such as aircraft machine guns, bombs, etc. were produced under the direction of the Air Service of the Army. Of this type of

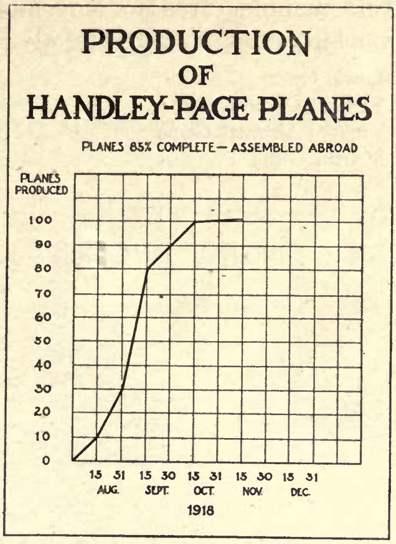


FIG. 6

PERFORMANCE

HANDLEY-PAGE PLANE

AMERICAN COMPARED WITH BRITISH

ENGINE		AMERICAN	2 LIBERTY
		BRITISH	2 ROLLS ROYCE
TOTAL BHP	AMERICAN	800	
	BRITISH	700	
POUNDS CARRYING CAPACITY	AMERICAN	5430	
	BRITISH	4700	
WEIGHT PER BHP-LBS	AMERICAN	17	
	BRITISH	19	
SPEED-MILES PER HOUR	AMERICAN	93	
	BRITISH	90	
SERVICE CEILING - FEET	AMERICAN	8500	
	BRITISH	8000	
CLIMB 8000 FEET	AMERICAN	72 MIN.	
	BRITISH	80 MIN.	
ENDURANCE - MILES	AMERICAN	600	
	BRITISH	600	

FIG. 7

material there were manufactured to November 11, 1918, a total of 81,754 machine guns for aircraft, divided as follows:

31,671	Lewis Guns
11,904	Vickers Ground Guns
411	Vickers Aircraft Guns
37,768	Marlin Guns

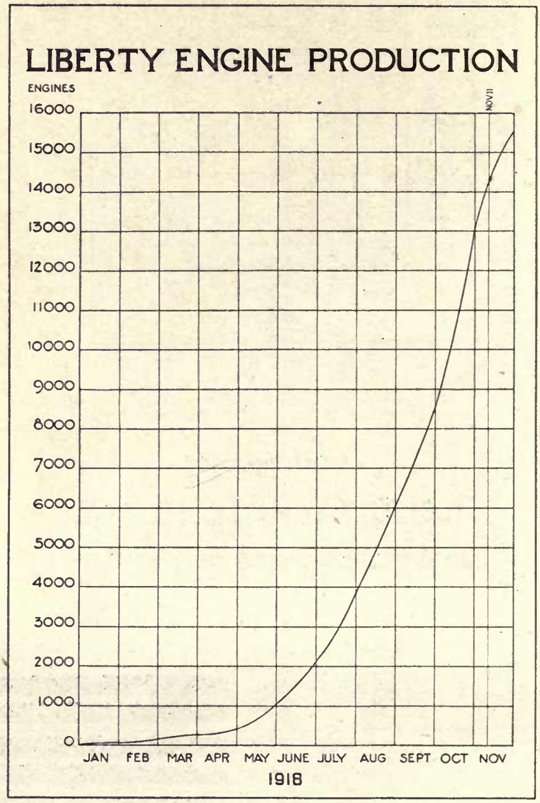


FIG. 8

with the following accessories:

Article	Number Produced
Flexible ring mounts	12,336
Ring sights	13,200
Wing vane sights	12,999
Unit sights	10,104
Auxiliary post and ring	4,585

A total of 510,271 bombs to be launched from air craft was produced to November 11, 1918, of which 114,809 were

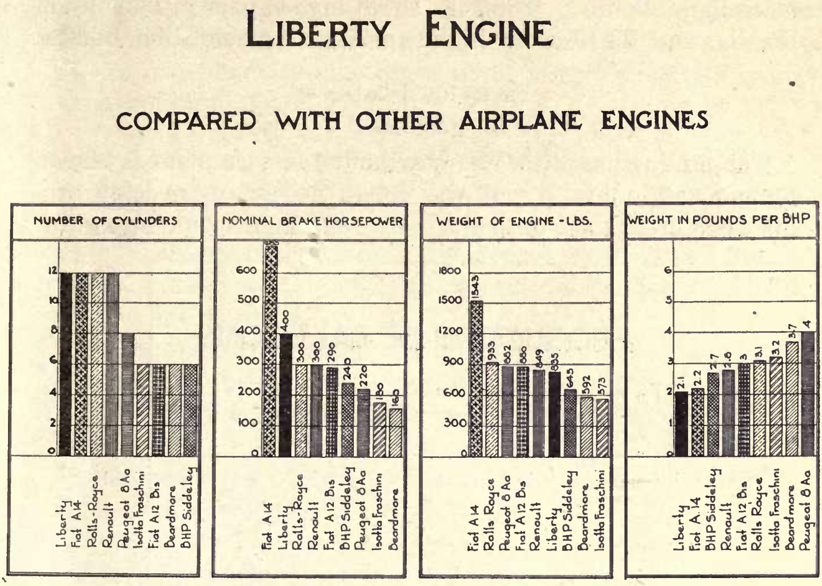

LIBERTY ENGINE
COMPARED WITH OTHER AIRPLANE ENGINES
NUMBER OF CYLINDERS
Liberty
Fiat A14
Rolls-Royce
Renault
Peugeot 8 Aa
Isotta Fraschini
Fiat A12 Bis
Beardmore
BHP Siddeley
NOMINAL BRAKE HORSEPOWER
Fiat A14
Liberty
Rolls-Royce
Renault
Fiat A12 Bis
BHP Siddeley
Peugeot 8 Aa
Isotta Fraschini
Beardmore
WEIGHT OF ENGINE - LBS.
Fiat A14
Rolls Royce
Peugeot 8 Aa
Fiat A12 Bis
Renault
Liberty
BHP Siddeley
Beardmore
Isotta Fraschini
WEIGHT IN POUNDS PER BHP
Liberty
Fiat A14
BHP Siddeley
Renault
Fiat A12 Bis
Rolls Royce
Isotta Fraschini
Beardmore
Peugeot 8 Aa

FIG. 9

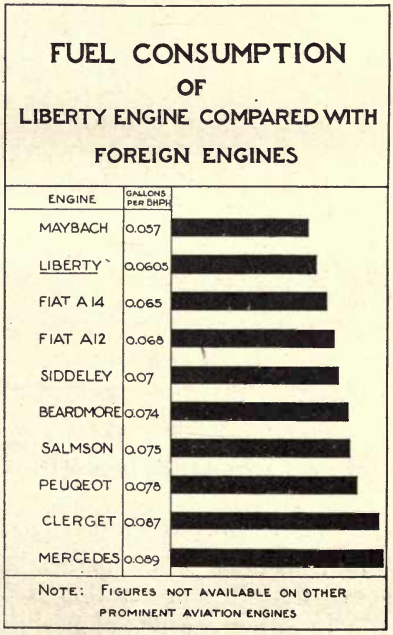

FUEL CONSUMPTION
OF
LIBERTY ENGINE COMPARED WITH
FOREIGN ENGINES
ENGINE
GALLONS PER BHP
MAYBACH 0.057
LIBERTY 0.0605
FIAT A 14 0.065
FIAT A12 0.068
SIDDELEY 0.07
BEARDMORE 0.074
SALMSON 0.075
PEUQEOT 0.078
CLERGET 0.087
MERCEDES 0.089
NOTE: FIGURES NOT AVAILABLE ON OTHER
PROMINENT AVIATION ENGINES

FIG. 10

incendiary bombs; 386,543 were high-capacity demolition bombs, and 8,919 were high-capacity fragmentation bombs.

Service Planes

DE HAVILAND 4

The production of the De Haviland 4 service plane is shown by months in Fig. 5. It was found necessary to delay production during the month of August 1918 that certain important

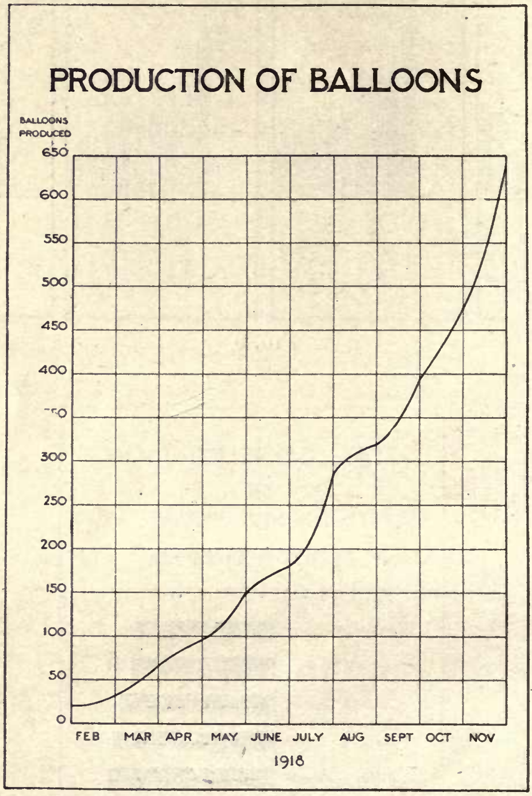


Fig. 11

changes, based on overseas experience with this plane, might be incorporated.

Handley-Page

The production of Handley-Page planes is found in Fig. 6. It should be noted that this production is for planes 85 per cent completed. In other words, planes shipped from this country were not assembled. Fifteen per cent was allowed for assembling abroad. The reason for shipping these planes

abroad unassembled is obvious when the size of the assembled plane is taken into consideration. An interesting comparison of the American Handley-Page plane with its British prototype will be found in Fig. 7.

Service Engines

More than 16,000 Liberty engines were produced during the calendar year 1918. To November 11, 1918, more than 14,000 Liberty engines were produced, equivalent to 5,700,000 brake horse-power. Fig. 8 shows the production of Liberty engines by months.

A comparison of the weight of the Liberty engine with some of the better known foreign airplane engines is shown in Fig. 9, and fuel consumption in Fig. 10. The basic data for Figs. 9 and 10 came from official communiques from abroad. In the case of the Liberty engine the results of more than thirty tests were averaged.

Balloons

The production of service balloons met all service requirements. Fig. 11 presents the production of balloons by months.

Types of American Machines Developed, Tested and Adopted for Production

On November 11, 1918, there had been developed, tested and adopted by the Army four airplanes, on which production would have started early in the present calendar year. They were the Lepere or L. U. S. A. C.-11 equipped with the Liberty engine, the U. S. De Haviland 9-A equipped with the Liberty engine, the Martin Bomber equipped with two Liberty engines and the Loening two-seater fighter equipped with the 300-h.p. Hispano-Suiza engine. The characteristics of these new airplanes are as follows:

Lepere or L. U. S. A. C. 11

Type: Two seater fighter — Engine: One Liberty

Weight empty with water	2468	pounds
Fuel and oil	475	"
Crew	360	"
Guns, ammunition, etc.	352	"
Gross weight	3655	"
Pounds per b. h. p.	10.15	"
Pounds per square foot	9.33	"
Speed at ground	136	mi. per hr.
Climb to 6500 feet	6	minutes

U. S. De Haviland 9–A

Type: Day bombing and reconnaissance Engine: One Liberty

As a Day Bomber

Weight empty with water	2815	pounds
Fuel and oil	933	"
Crew	360	"
Guns, ammunition, etc.	764	"
Gross weight	4872	"
Pounds per b. h. p.	13.5	"
Pounds per square foot	9.5	"
Speed at ground	121.5	mi. per hr.
Climb to 6500 feet	11	minutes 40 seconds

As Reconnaissance Plane

Weight empty with water	2815	pounds
Fuel and oil	933	"
Crew	360	"
Guns, ammunition, etc.	214	"
Gross weight	4322	"
Pounds per b. h. p.	12	"
Pounds per square foot	8.4	"
Speed at ground	126.2	mi. per hr.
Climb to 6500 feet	7	minutes 30 seconds

Loening

Type: Two seater fighter Engine: One 300 HP Hispano

Weight empty with water	1130	pounds
Fuel and oil	290	"
Crew	360	"
Guns, ammunition, etc.	828	"
Gross weight	2608	"
Pounds per b. h. p.	8.7	pounds
Pounds per square foot	12.1	"
Speed at ground	143.5	mi. per hr.
Climb to 6500 feet	5	minutes 12 seconds

Martin Bomber

Type: Night Bomber Engine: Two Libertys

Weight empty with water	5862	pounds
Fuel and oil	1492	"
Crew	540	"
Guns, ammunition, etc.	1769	"
Gross weight	9663	"
Pounds per b. h. p.	13.4	"
Pounds per square foot	9	"
Speed at ground	113 3	mi. per hr.
Climb to 6500 feet	10	minutes 45 seconds

In order that intelligent comparisons may be made, there are submitted below characteristics of the De Haviland 4 plane:

Engine	One Liberty	
Weight empty with water	2391	pounds
Fuel and oil	457	"
Crew	360	"
Guns, ammunition, etc.	374	"
Gross weight	3582	"
Pounds per b. h. p.	8.95	"
Pounds per square foot	7.12	"
Speed at ground	124.7	mi. per hr.
Climb to 6500 feet	8	minutes

The Naval Sea-Plane NC-1

One of the most striking accomplishments of the United States in airplane design has been the development by the Navy of the Naval Seaplane or flying boat NC-1. This plane has a central float 46 feet long, a wing span of 126 feet and a total wing area of 2400 square feet. This plane is equipped with three Liberty engines with tractor screws. Fully loaded the plane weighs 22,000 pounds. The weight empty with water is 14,000 pounds.

This plane is the largest seaplane in the world, at the moment, and is an American product throughout. The hull was designed after tank experiments on models. On a recent test this plane made a flight at Rockaway Beach, New York, with fifty-one passengers aboard, getting off in fifty-three seconds. Upon landing it was discovered that the fifty-first passenger was a "stowaway" on board the plane.

III—Remarks on Instruments, Raw Materials and the Training of Personnel

Instruments

THE facilities for the manufacture of instruments necessary to give airplanes, pilots and observers their greatest usefulness were extremely limited at the outbreak of the war. The making of these instruments involved practically the formation of an industry new to this country. By June, 1918, twenty types of instruments were in production and being supplied for installation in training, bombing and fighting planes. The list included airspeed indicators, altimeters, compasses, safety belts, oxygen apparatus, radio sets and all other necessary adjuncts for the navigation of the air, and for the safety and comfort of the pilot.

Looking into the future, a reliable and simple "turning indicator" for airplanes is much desired. Furthermore, the development of some form of gyroscopic compass to meet the severe conditions of aircraft service is a problem of great importance. It has been said that the magnetic needle has sense but no power, and the gyroscope has power but no sense.

Spruce Production

Some idea of the magnitude of the task involved in the procurement of the principal raw material used in the construction of the plane proper, namely spruce, may be obtained from the following figures on production and personnel. On June 30, 1918, the spruce production personnel consisted of 18,305 officers, enlisted men and civilians. Railroads were constructed into the forests of the West Coast and a cut-up plant having a maximum capacity of 9,000,000 board feet of lumber a month was erected at Vancouver Barracks near Portland, Oregon. To November 11, 1918, approximately 174,000,000 board feet of spruce and fir, as shown above, had been shipped of which more than two-thirds went to our Allies.

Linen, Dope and Oil

As it was impossible to produce the millions of yards of linen fabric required for airplane wing and body covering, a suitable cotton substitute was developed and manufactured in this country in quantities sufficient to meet the needs of both

America and the Allies, and at a cost slightly more than half that of the linen fabric formerly used. This accomplishment, theretofore thought impossible, ranks among achievements of the first importance. The dope used on the fabric of airplanes presented many difficulties not only to us but to our Allies. This and other chemicals required soon were being produced in this country in quantities sufficient for their requirements as well as our own.

To meet the extensive demands for a high-grade lubricating oil, castor bean seeds were imported from India and about 108,000 acres planted in this country. Meanwhile, research work with mineral oils was carried on intensively, with the result that lubricant was developed which proved satisfactory in practically every type of airplane engine, except the rotary engine, in which castor oil still is preferred.

Training of Personnel

The personnel side of the Air Service, including the selection, training, organization, and operation of the flying forces, developed within the fiscal year 1917-18 into an educational system on a scale infinitely larger and more diverse than anyone had anticipated. Teaching men to fly, to send messages by wireless, to operate machine guns in the air, to know artillery fire by its bursts, and to travel hundreds of miles by compass, teaching other men to read the enemy's strategy from aerial photographs, and still others to repair instruments, ignition systems, propellers, airplane wings, and motors, has required a network of flying fields and schools, a large instructional force, and a maze of equipment and curricula.

IV—Some Remarks on the Physical Conception of the Air.

IN a very condensed form I have endeavored to present in the above outline, the salient facts and figures of actual production and deliveries in connection with the air program in the United States up to the moment of signing the armistice. These figures are the cold facts of actual accomplishment of finished product.

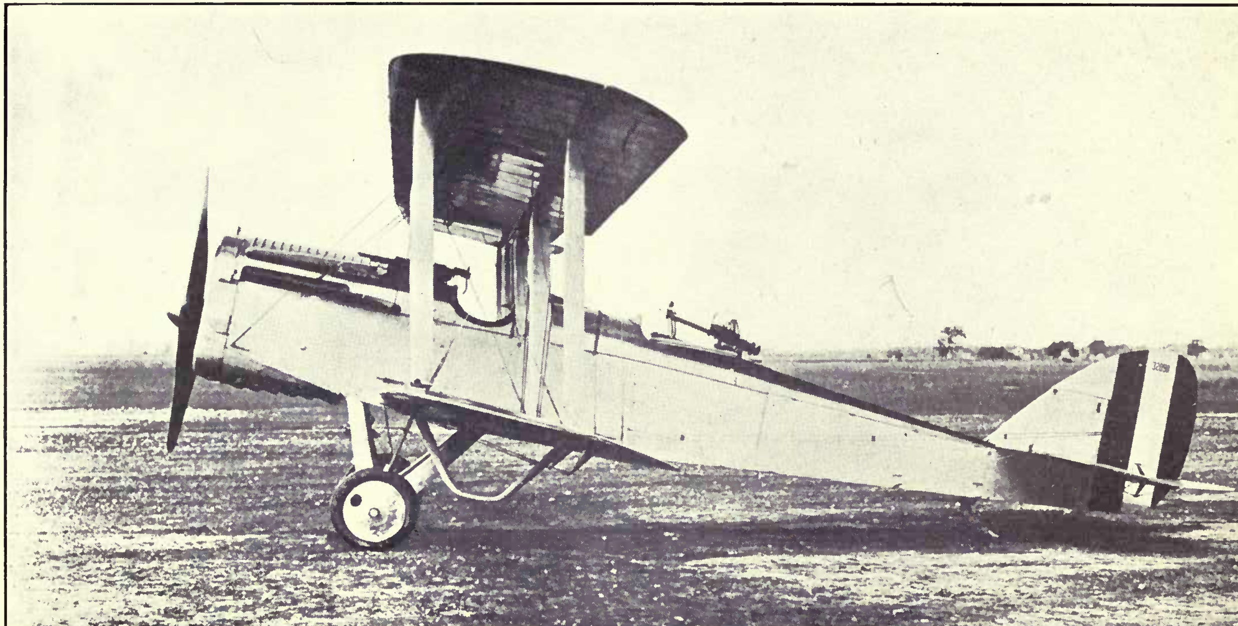
I have made no exterpolations to these production curves which would show what flow of Liberty engines and combat planes for instance, we reasonably could expect would result in the succeeding months following the signing of the armistice. I leave this exterpolation to those of you who may be curious.

Behind the production figures of November 11 was mobilized in the United States an industrial army of about 350 firms and corporations employing more than 200,000 men and women. A huge imaginary conduit leading from the factories and assembly shops of America to the fighting front in France was in operation. At any given moment, the number of engines, planes and accessories distributed along the 3000 miles of this imaginary conduit were known accurately and organized in such a way that the flow throughout should be continuous, or that minimum congestion should occur at any point, be it factory door, railway train, embarkation depot, steamship, or debarkation point in Europe.

In order, however, to give an adequate idea of our whole effort, it will be necessary to refer now to certain lines of development, some physical, some chemical and some physiological, which have been set in motion during the progress of this work.

I think we will admit that no world-movement such as we now are witnessing in the development of aerial navigation demands such a close union between science and art. To make a machine to go into the air to transport man is a task set for the hand and brain as never before.

Fifteen years seems a short time when we contemplate what has been accomplished; yet, it was only fifteen years ago, on December 17, 1903, that Wilbur Wright made the first successful flight in a heavier-than-air machine at Kitty Hawk, N. C. To-day Government airplanes have carried the mail between



De Haviland 4—Liberty Engine

[Squier]

Washington and New York for seven months, and few of us take the trouble even to watch for these daily flights.

The advent of the first heavier-than-air flying machine begat, as a consequence, a period of intensive interest and study of the physical and dynamical properties of the medium, which are only now in the early beginning, and whose ultimate extensions we can only dimly perceive.

In November, 1916, I had the honor of addressing the National Academy of Sciences at Boston and outlining at that time some outstanding problems for research in connection with aeronautics. Although this was only two years ago, such has been the activity in research in studying air problems that fully two-thirds of the subjects suggested at that time now have been satisfactorily solved and are in actual use in the art.

Technical courses have been established at universities and colleges, and the new profession of Air Engineering is at the moment vying with the older engineering branches.

Everyone knows, of course, that if there were no air there could be no life, but probably very few fully realize its immense importance in almost everything we do. In one condition it is invigorating and gives us a zest for hard work whether mental or physical; in another it leaves us depressed and incapacitated for efficient labor. Numerous manufacturing processes are radically affected by the amount of moisture in the air, and many others by its temperature. Power is transmitted by it; we communicate our thoughts to one another by vibrations of the air; and by its aid we recently have acquired our swiftest mode of travel. Obviously then, a knowledge of the composition, structure, and physical properties of this universal medium is of such vital importance as to justify most painstaking study and research.

In the last few years, for instance, several elements: helium, argon, neon, krypton, xenon, have been found in the atmosphere that previously were unknown and even unsuspected, for they were not required by the Mendeleoff table of the elements as then understood. One of these, argon, amounts to nearly one part in a hundred of the whole atmosphere, and yet through decade after decade of chemical investigations involving countless thousands of air analyses, it, and all its family of gases, remained undiscovered.

Recently, too, means have been found for drawing directly on the atmosphere for an inexhaustible supply of nitrogen

compounds used in the production of powerful explosives, fertilizers, and many other things of industrial value.

The first eighteen years of the present century have witnessed a wholly new and startling flood of physical knowledge which has resulted in profoundly modifying our conceptions of electricity and matter, as developed in the nineteenth century. These two great subjects have been brought together and now are recognized as one and the same subject.

What we called self-induction now is considered to be only inertia. Mass is supposed to be wholly electrical and a vector instead of a scalor quantity. The most fundamental of all physical constants, the electron, has been isolated and its charge measured. Electricity from whatever source is made up of these electrons and even metallic conduction consists of the actual projection of these granular units along the conductor.

A gas like the air, on the present view, is not a continuous medium, but is composed of many individual structures which preserve their indentity and individuality during the normal life of the gas. These largest units are known as molecules, and they are each moving with considerable velocity on the average, the path of each being for the greater part a straight line until two approach near to each other. The forces that these two exert upon each other reach out into the medium which surround them both, creating a region of intense field at sufficient distance away from each so that their integrity is not disturbed.

When the two molecules approach each other, they are deflected off without collision, preventing a catastrophe much as a comet coming into the solar system is merely deflected by the action of the sun, and does not fall into it unless it makes a direct hit, the chances of which are extremely small. The gas pressure of the air upon the walls of the containing vessel merely is the reaction of these deflected molecules that come into close proximity with the more fixed molecules of the container.

If we consider for a moment a cubic centimeter of air under standard conditions, we know that the number of the largest structures therein, the molecules, is a constant, and is about 2.705×10^{19}. It does not matter what kind of a gas we have, whether hydrogen, oxygen, nitrogen or compounds like methane carbonic acid, etc; the number of molecules remains fixed. In fact, we probably can determine the number of molecules in a

cubic centimeter of a gas more accurately than we can determine the number of inhabitants in New York City, in spite of the fact that the number is slightly more than twenty-seven billion billion.

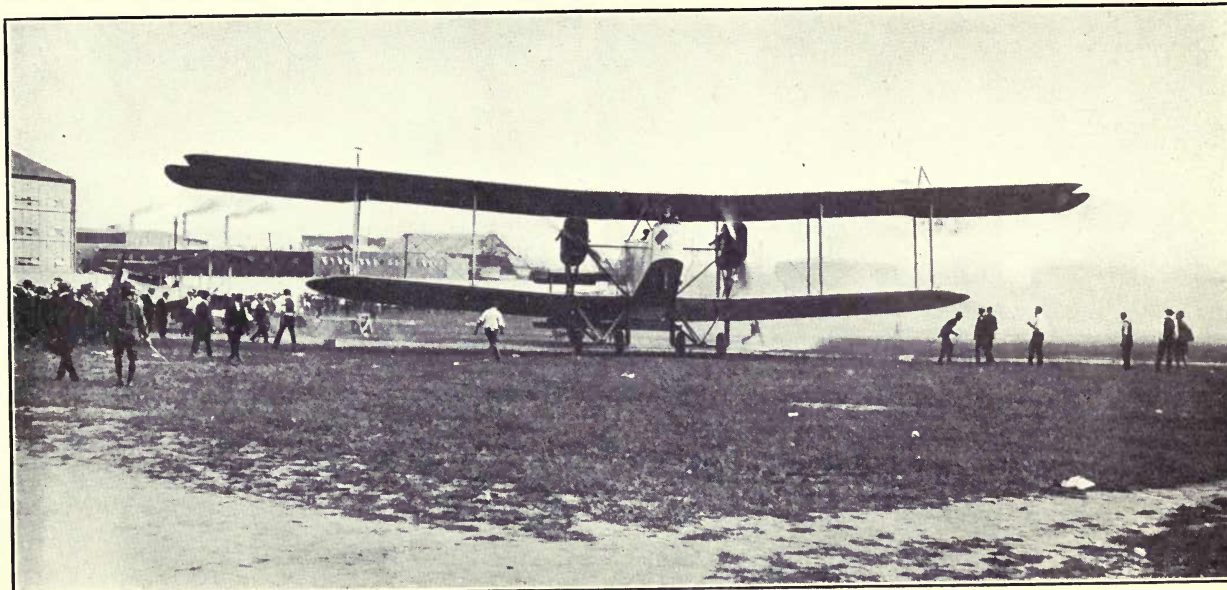
By measuring the weight of the cubic centimeter of air and dividing this by the number of molecules contained therein, we obtain the weight of the largest structure composing the air, namely, the molecule. The structure of the molecule, while sufficiently enduring to remain together as a unit in the normal condition of the gas, yet is not strong enough to withstand forces that may be easily brought to bear upon it by chemical means to cause it to separate into still smaller units known as atoms. In the nitrogen and the oxygen of the air there are but two atoms making up each molecule, so that each structure in air can only be divided into two by any means at the disposal of the chemist.

The atoms, however, have been broken up into still smaller units, but it can be done only with great difficulty, comparatively speaking, and until recently, the difficulty was so great that they earned the name atom, signifying that they could not be cut in two. They are far more enduring structures than the molecule.

The only two kinds of things that ever have been obtained thus far by the breaking up of the atoms, of all kinds, are the so-called positive ions and negative electrons, and these remain today as things which never have been broken up into smaller components. Whereas the negative electron has been isolated from gross matter the positive charge never has been dissociated from matter. The present idea of physicists is that we have found an ultimate constituent of all gross matter. The mass of this negative electron has been measured, and the mass of the smallest atom, hydrogen, is 1845 times greater than that of the electron.

We regard the atom as consisting of a positive nucleus about which negative electrons are ceaselessly revolving. The dimensions of the negative and positive constituents of atoms, in comparison with the dimensions of the atoms themselves are like the dimensions of the planets and asteroids in comparison with the size of the solar system. Here then the master physicists with consummate skill have built up for us an alluring conception of miniature solar systems of which all gross matter is composed "A mighty maze! but not without a plan."

In the light of the foregoing conception of a cubic centimeter of air, imagine if you can, what a compilcated thing is the result of an orchestra playing perhaps one hundred instruments and two hundred voices singing in chorus, accompanied by the orchestra. The cubic centimeter of atomic worlds, in this case, becomes subjected from without to a great number of superimposed frequencies representing each and all of the individual instruments, as well as the innumerable harmonics required to indicate the qualities of the human voices; yet our medium is sensitive enough to respond accurately to each and every one of these frequencies simultaneously, and synthetically adds them together and produces a resultant envelope curve of pressure which the marvels of the human ear are able to analyze and interpret into its elements. A medium which has such qualities as to be capable of acting and reacting in this delicate manner, and at the same time when moved bodily with the velocity of a tornado may cut down trees and buildings as if by a giant steel knife, is a medium the possibilities of which for future research we, at present, only dimly perceive.



HANDLEY-PAGE BOMBING PLANE—TWO LIBERTY ENGINES

[SQUIER]

V—The Production of Helium on a Commercial Scale

ONE of the greatest scientific achievements of the present war from a technical standpoint is the production of helium in balloon quantities. This gas is non-inflammable and has about 92 per cent of the buoyant effect of hydrogen. Its name is due to its having been discovered in the sun's atmosphere through a characteristic line in the solar spectrum, before its presence on the earth, or any of its properties were known. It first was obtained in minute quantities by Ramsay in England some twenty years ago by heating certain radioactive minerals, in which it occurs because it is a disintegration product of radium. Its pre-war scarcity may be appreciated from the fact that, up to two years ago, not more than 100 cubic feet ever had been obtained, and the usual selling price was about $1700 a cubic foot.

Notwithstanding so discouraging an outlook someone in the British Admiralty had imagination enough to propose the large scale separation of helium from certain natural gases in Canada, that contain about one-third of one per cent of it, and experiments were undertaken at the University of Toronto. Soon after the entry of the United States into the war, the Bureau of Mines, learning of the problem from a British confidential memorandum, persuaded the Signal Corps and the Bureau of Steam Engineering of the Navy to approve and finance jointly an experimental program on a large scale. Thanks partly to the unusually rich sources of supply in this country, and partly to the skill of the two commercial companies whose services were enlisted, and to the enthusiasm of the Bureau of Mines Staff and of Mr. Carter, of the Navy, who for a time represented the Army as well in the project, such success was achieved that, at the cessation of hostilities, there was compressed and on the dock ready for floating 147,000 cu. ft. of nearly pure helium, and plants were under construction to give at least 50,000 cu. ft. a day at an estimated cost of not more than ten cents a cubic foot.

The production of a balloon gas that assures safety from fire opens up a new era for the dirigible balloon. In November, 1917, a Zeppelin made the trip from Bulgaria to German East Africa with twenty five tons of medicines and munitions, only to find that the German forces already had been dispersed, and returned safely to its base without landing. With a non-inflammable gas, not only comfortable and expeditious, but also safe transcontinental and transatlantic travel in dirigibles will, it is believed, soon be commonplace.

VI—Meteorological Service of the Army

IN August, 1917, the Chief Signal Officer directed Lieut. Colonel R. A. Millikan to organize an Army Meteorological and Aerological Service, the purpose of which was three-fold:

a. To provide the American Expeditionary Forces with all the meteorological and aerological information needed.

b. To supply the aviation fields, the coast artillery stations, the ordnance proving grounds, and the gas warfare service within the United States with such meteorological and aerological data as might be useful to them.

c. To undertake for the first time in the history of the world the problem of mapping the upper air currents over the United States, the Atlantic, and Western Europe in aid of aviation, and particularly with reference to transatlantic flight.

In carrying out the first of these projects, there were selected approximately 550 men of high qualifications, most of them physicists or engineers who were given a two months' course in meteorological and aerological theory and observations at College Station, Texas. Three hundred and fourteen of these men were sent overseas where they have been operating as an effective and well organized branch of the work of the A. E. F. In addition to furnishing a general weather forecast for the A. E. F., this service has supplied a meteorological unit to each aviation post, each gas service post, each artillery post, and each sound-ranging post of the American Army in France. Under the effective direction of Major W. R. Blair, one of the most experienced aerologists of the United States, commissioned for the service from the Weather Bureau, about twenty upper-air stations were established in France and England and a forecast based on data furnished by these stations made regularly to the A. E. F.

For the accomplishment of the second element of the program, twenty eight stations manned by 150 men, all carefully picked at the start and well trained at College Station, have been established for furnishing local data as to either surface or upper-air conditions, or both, to the flying fields, artillery posts, and proving grounds in this country. The largest of these stations is that at the Aberdeen Proving Ground, which is manned by twenty two men and furnished to the Bureau

of Ordnance all necessary data for the determination of ballistic wind which, in view of the development of high angle fire, has become altogether indispensable for the construction of range tables needed for obtaining accuracy in the work of the artillery.

In carrying out the third element of the program, twenty-six meteorological stations were established, placed at carefully selected points over the whole of the United States, which stations have been manned by trained observers who telegraph to Washington each day observations on wind velocities at all altitudes up to 35,000 feet. In one instance these observations have been carried to 65,000 feet. On the basis of these observations, a daily forecast of upper-air winds is now being issued. The use which such forecasts may serve, both in connection with the aviation mail service and ultimately with the trans-atlantic service, may be seen from the fact that above the level of 10,000 feet, 95 per cent of the winds in both the United States and Europe are from West to East and often attain velocities in excess of 100 miles an hour. On November 6, 1918, at Chattanooga, Tennessee, a velocity of 154 miles an hour at an altitude of 28,000 feet was observed. It is because of this easterly direction of these upper air currents that all of the long flights thus far made have been from West to East. The importance of a forecast of such currents for the purpose of long flights will be appreciated as soon as the foregoing facts are understood. An airplane capable of a velocity of 154 miles an hour in still air either would remain stationary or travel at 308 miles an hour depending on whether it was headed into or with a wind of the velocity of that observed at Chattanooga.

All of the aerological work so far mentioned has been done with the aid of theodolites especially designed by Major W. R. Blair for this service. Sixty of these have been built for the work in this country and twenty shipped abroad.

The problem of exploring the upper-air currents over the Atlantic was at first thought insoluble on account of the absence of fixed bases, but the Meterological Service has developed propaganda balloons which already have flown at an average altitude of 18,000 feet from Omaha to New Jersey, a distance of more than a thousand miles. The success of the project now has made possible the mapping of the upper-air highways across the Atlantic; for arrangements are being made to send

up from both coastal stations and from transatlantic steamers, these long-range balloons designed for from two to three-thousand-mile flights, and adjusted to maintain a constant altitude and to drop in Western Europe their records of average winds in these heretofore unchartable regions. The importance of this work for the future of aviation needs no emphasis.

The success which the Meteorological Service has attained would have been wholly impossible had it not been for the intimate and effective cooperation which has been extended to it in all of its projects by Director C. F. Marvin and the entire staff of the United States Weather Bureau.

VII—Physiological Study of the Flier

UNTIL a year and a half ago, interest centered in the development of aircraft and not in the flier. There was little regard for the special fitness of the man on the day and hour he drove his machine.

This was true, not only in the United States, but also in the Allied countries. The pilot was not selected because of any peculiar fitness for flying. It simply was a question of whether or not he had the nerve.

But, about the time the United States entered the war, it became clear that the science of physiology could be applied with advantage to the selection, classification and maintenance of the aviator. Each of the countries in the war now has a fully established air medical service, as an integral part of the air forces. In the British Army there is a separate air medical service with a Surgeon General of Aeronautics. In the American Army this work has been handled effectively by a division of the Surgeon General's office, assigned as part of the Air Service.

The early view that any one who "had the nerve" could fly caused enormous avoidable wastage of life and material. The lesson learned from bitter experience was that it is essential to obtain fliers who are especially fitted for particular work and to keep them in condition to perform their duties at all times.

Nature never intended man to fly in the same sense that she did not intend him for life in a submarine. Conditions are unnatural from the time he leaves the ground until he returns. There are many obstacles to overcome. He flies in an atmosphere deficient in that oxygen which is the "breath of life;" he is subjected in war to the shells of anti-aircraft guns and enemy aircraft; he travels through space high above the ground at rates well in excess of 100 miles an hour. In attaining altitudes and breathing rarefied air, the flier is defying nature.

The pilot is the heart and brain of the whole flying apparatus. Parts of the airplane may break without serious result, but when the pilot breaks, even momentarily, nothing is left to direct the flight. The man and the machine come crashing to the earth.

All this the Air Medical Service had to consider. The

service had the advantage of a series of reports of the air medical services of our Allies, which enabled it to attain self-footing in a remarkably brief time. A medical research laboratory, fully equipped, was established by the Army Air Service at the flying fields on Long Island, N. Y.

The keynote of the American Air Medical Service is the handling of the flier as an individual, which naturally brings the work into three main divisions:

First, the selection of the flier:

Second, the classification of the flier, and

Third, the maintenance of the physical efficiency of the flier.

The Selection of the Flier

The outset of the war made it necessary to obtain a large number of military aviators in the shortest possible space of time. The medical problem consisted of selecting men who were physically fit.

It is possible for men to fly in spite of one or more physical handicaps, such as having only one leg or one eye or even being cross-eyed, but such men are not desirable fliers, since men with complete endowments naturally have superior advantages. The man in the flying service would be called upon to negotiate critical emergencies in the air. Instant decision and action, therefore, would be essential for success. So it was seen that only those men with exceptional mental and physical capabilities should be chosen.

In order to accomplish the best results, a comprehensive program was undertaken, providing for the standardization of both tests and examiners. Sixty-seven military units were established, each examining from ten to sixty applicants a day. The figures show that 70.7 per cent of the applicants were qualified. The large number of applicants made it possible to maintain the highest standard in selecting men.

In the same spirit with which the United States determined to supply the American air fighters with as good, if not better, planes than those used by the enemy, it was decided that the American aviators must be as good if not better than those of the enemy. The outcome of any encounter might easily depend upon which combatant possessed the better vision and other special senses, the better nervous system, and the better mental and physical equipment in general.

Each applicant received a complete physical examination

embracing all the features ordinarily required of men entering the military service, and, in addition, comprehensive and extensive tests of the special senses of vision, hearing and motion sensing.

Classification of the Flier

It is important to classify the flier for the kind of work he is physically capable of performing. Some men are not able to fly at higher levels than a few thousand feet without serious deleterious effects, while others may operate at much higher altitudes. It is necessary to know a flier's limitations before his training is specialized, for the saving of time and money, and, in fact, the flier himself. It would be an evident waste to train a pilot for combat work and then find he was physically capable of doing only bombing at a relatively low level. To accomplish this classification, branch medical research laboratories were placed in the flying fields, which by appropriate tests on the rebreather machine, developed at the parent institution at Mineola, classified the fliers.

The work of these laboratories demonstrated that sixty-one per cent are capable of flying to 20,000 feet or more, twenty-five per cent should not fly above 15,000 feet, and fourteen per cent were unsafe above 8,000 feet.

The re-breather is used also to determine temporary unfitness for altitudes, due to some intercurrent illness, dietary indiscretion and staleness from prolonged flying.

The necessity for altitude classification is readily understood from the fact that whereas in 1915 flying rarely exceeded 8000 or 10,000 feet, through improved design, scouts of today climb to altitudes of 25,000 feet within a very short time.

Night bombing is carried out at altitudes as low as 300 feet. Day bombing, in order not to reveal the objective of the flight and to guard against concentrated anti-aircraft fire, may call for flights at extremely high altitudes. Reconnaissance machines rarely get to high altitudes, owing to the necessity for more or less close observation of the ground, and machines doing this work accomplish low flying even in the face of highly concentrated anti-aircraft fire, and other enemy activity. Machines cooperating with the artillery making range corrections for batteries, do not often work above 6000 or 8000 feet.

Owing to the fact that all this work is widely diversified, it is essential that each man be placed in that division for which he is best suited. A knowledge of the limitations of a valuable

man spells increased efficiency. Just as the pilot is provided with a certain type of plane adapted to the work in hand, so the plane must be provided with a pilot adapted to the work.

Fliers who are forced to undergo abrupt changes in atmospheric pressure and oxygen supply must be singled out. Atmospheric pressure plays an unimportant role; the whole problem resolves itself into a deprivation of the normal oxygen supply.

The Flack bag was the prototype of the rebreathing apparatus which has been developed in the medical research laboratory. By means of this apparatus the aviator rebreathes air confined in a tank, from which he gradually consumes the oxygen. As the percentage of oxygen decreases, the flier, in effect, is slowly ascending to higher altitudes. In the course of twenty-five to thirty minutes he lowers the oxygen content of the air in this tank to 8 or 7 per cent, which is equivalent to attaining altitudes of 25,000 to 28,000 feet.

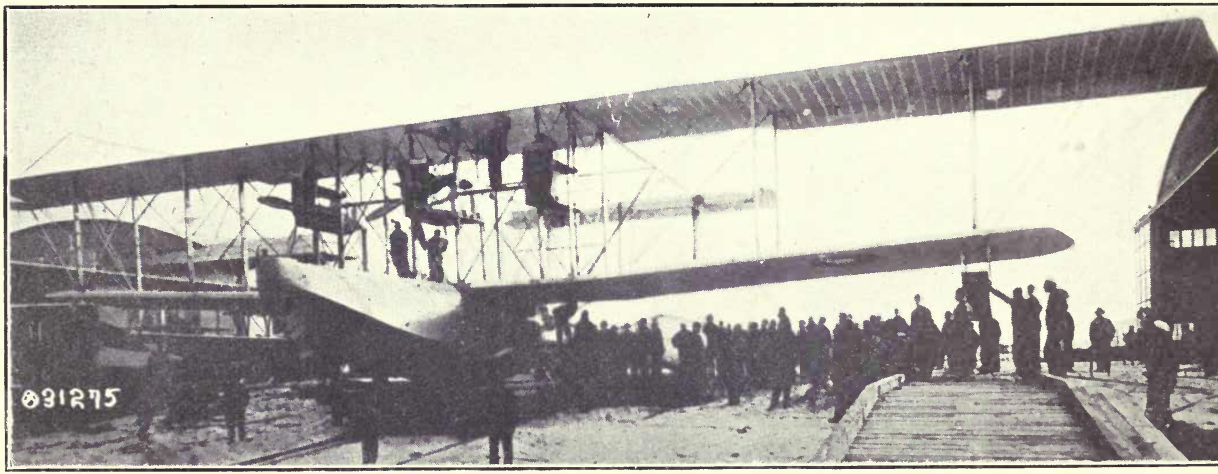
Another means of attaining the same result is by the diluting apparatus, which supplies directly to a mask over the face a mixture of air and nitrogen in whatever proportion is desired. All of these tests have been standardized and confirmed by the low-pressure tank, in which the air is rarefied to correspond to any given altitude.

By a comparison of the percentage of oxygen to which the flier succumbs when on the low-oxygen test, it is possible to determine the altitude at which he would fail were he in the air. This determination is made on the ground, without danger either to the flier or to his machine.

The effect of low oxygen upon the mental processes varies greatly in the individual. He usually becomes mentally inefficient at an altitude at which there is as yet no serious failure of his vital bodily functions. By simple tests of mental alertness during rebreathing it is easy to determine that one flier becomes mentally inefficient at 15,000 feet, in sharp contrast to another who has his full mental powers up to and beyond an altitude of 25,000 feet.

Oxygen-want exaggerates any latent defect of the eyes. Crash reports have demonstrated that a large proportion are due to eye defects.

"Stunting" essentially is an internal-ear problem. During and after rapid turning the flier's brain is receiving impulses from his semicircular canals. In a normal individual nothing



N. C. 1 NAVY SEAPLANE (OR FLYING BOAT)—THREE LIBERTY ENGINES [SQUIER]

can control or alter the sending or receiving of these impulses, which produce sensations of motion. Fliers vary greatly in their ability to interpret correctly the significance of these impulses. Experience alone enables them to familiarize themselves with their meaning. Those who develop the greatest ability in their interpretation naturally fall into the scout-pursuit class. Those who, in spite of training, are still disturbed or bewildered by stunting are reserved exclusively for straight flying.

The Maintenance of Efficiency

When the work of selection and classification is completed, the great problem of the Air Medical Service is to maintain the fliers on a basis of high physical efficiency.

After a certain amount of continuous service the flier begins to show unmistakable signs of deterioration. Until the Air Medical Service went to work, fliers were permitted to continue until they broke. Their breaking was signalized sometimes by simple failure to return from behind the enemy lines; sometimes by becoming mentally and nervously exhausted to the extent of permanently unfitting them for flying.

The rebreathing test also is valuable in determining this staleness in fliers, caused by frequent exposure to high altitudes. Incipient cases of the deterioration of efficiency caused by oxygen-want are detected easily by means of the rebreather. Then it is possible to ground a man for a certain period to enable him to recover entirely, whereas if this condition were not detected, it might progress to a point where it would be impossible for the man to regain his former efficiency. When staleness becomes marked the flier is liable to faint in the air, thus losing his life and wrecking his machine. Periodical examinations are made to detect staleness.

There are three and only three means by which the flier's usefulness may be terminated; first, by the enemy; second, by the failure of the machine; and third, by the failure of the flier himself.

While it was not possible to arrive at exact percentages, estimates made at the time of our entrance into the war, based upon information from Italy, France and Great Britain, indicated that not more than two per cent. of the aviation losses in active service were caused by the enemy. Failures of the airplane were responsible for only slight losses, due, of

course, to the rigid inspection of the machines. Statements from all sources agreed that of the total number of fliers permanently out of the flying service, not more than 8 per cent could be attributed to mechanical shortcomings of the airplane or engine.

The remaining 90 per cent loomed large when it was realized that this proportion represented trouble in the flier himself.

Therefore the "Flight Surgeon" was authorized to keep aviators physically fit and to study the causes of accidents attributed to the failure of the man.

Keeping the flier fit embraces the amount of physical exercise necessary; the provision of proper recreation; the state of fatigue of the individual; the amount of sleep; the provisions for leave or furlough; the food problems; the field conditions bearing on his welfare, and his reexamination at frequent intervals.

It was observed that more than half the injuries in crashes were caused by the flier striking his head against the cowl. The cowl was cut out to give the flier more room in front, and this change has practically eliminated the head injuries. A safety belt was lashed to the machine by a simple rubber shock absorber, and since this has been done the number and extent of injuries to the upper abdomen and ribs have been reduced decidedly. The problem of protecting the flier against the extreme cold of high altitudes in winter was solved by designing electrically warmed clothing. The problem of enabling the flier to withstand the glare reflected sunlight above cloud banks was solved by furnishing him with the "Noviol" type of goggles. The Dreyer oxygen apparatus is used to compensate for his lack of sufficient oxygen in high altitudes. This apparatus has been so modified and perfected that it is now possible to automatically supply a flier with the correct amount of oxygen for the altitude at which he is flying.

All this has been done toward reducing this "ninety per cent," and much more is being developed. Within the last few months an apparatus has been perfected whereby students may acquire flying experience and training without leaving the ground. This machine, known as the Ruggles Orientator, is a modification of the universal joint, composed of three concentric rings so pivoted as to permit the fuselage, which is pivoted within the innermost ring, to be put through every possible evolution experienced in actual flying, except forward progression.

An analysis of "crash reports" shows that a large number are due solely to failure to come out of the spinning nose dive or tail spin. The student failed in these maneuvers because he had not learned to compensate by sufficient previous experience for his dizziness. The new apparatus gives the flier experience until he becomes familiar with the various sensations.

Another method of educating the student is by means of flying calisthenics. By daily turning and tumbling exercises he becomes accustomed to positions and movements in which at first he is awkward and bewildered.

It has become evident during the last nine months through activities of nutritional survey parties of the Food Division, Surgeon General's Office, that there is a great need in each aviation camp for a nutrition officer. The nervous system is more highly differentiated than the muscular system, and more easily upset by improper food. It has been shown that a nutrition officer with special knowledge of food values should supervise the messes of all cadets and officer fliers in order to keep up efficiency.

Under date of November 20, 1918, General Pershing says in a report to the Secretary of War: "Our aviators have no equals in daring or in fighting ability, and have left a record of courageous deeds that will ever remain a brilliant page in the annals of our Army."

The work of the Air Service Division of the Surgeon General's Office was instituted by Major, now Brigadier General T. C. Lyster, with the assistance of such specialists as Colonel George H. Crabtree, Colonel William H. Wilmer, Lt. Col. E. G. Seibert, Lt. Col. Isaac H. Jones, Lt. Col. Eugene R. Lewis, and Lt. Col. Ralph H. Goldthwaite.

VIII—Activities of the Bureau of Standards for the Air Service

Radio Investigations

A THOROUGH study of vacuum tubes for use in transmitting, receiving, and amplifying is in progress; a study of insulating materials used in radio apparatus; the development of a permanent contact crystal detector; the development of a high-frequency oscillographic equipment; the furnishing of standards for use in radio development are among the subjects handled in connection with the production of radio apparatus for military purposes.

The facilities of the laboratory and working quarters have been provided for the Research Laboratory of the Science and Research Division of the Signal Corps, and the Intelligence Division of the Signal Corps.

Aerodynamic Investigations

The wind tunnel of the Bureau of Standards has been employed in a wide variety of military problems, among which may be mentioned the following:

Bomb-dropping devices have been tested and compared. The head resistance and other characteristics of airplane bombs have been measured in order to provide data for computing the trajectories. Machine gun sights for airplane use, with automatic adjustments for speed have been tested and adjusted in the wind tunnel. Hundreds of Pitot tubes and Pitot-Venturi combinations for measuring the speed of the airplane have been calibrated. The head resistance of many types of engine-radiator sections has been measured. Small variable-pitch propellers for driving at constant speed the generator used in radio signaling, independently of the speed of the airplane or engine were perfected through wind tunnel tests and later tested in large numbers. Finally, the characteristics of new wing-sections and new airplane designs have been determined from wind tunnel tests on models.

Aeronautic Power plants

An altitude laboratory for the study of airplane engine characteristics and performance at all flying altitudes was

begun in August, 1917, completed in January, 1918, and has been in service since that time.

Studies have been made of the Liberty "8" and Liberty "12", Hispano-Suiza 150 h. p., Hispano-Suiza 180 h. p., and Hispano-Suiza 300 h. p. models.

The results include complete data as to the power developed, fuel consumptions and heat balances at all practicable engine speeds and altitudes up to 30,000 feet; the demonstration of causes of bad carburetion at high altitudes and of the requirements for the best results, together with the development of means for producing these results automatically; the analysis of the effect of fuel composition on engine performance, the results of which served as the basis of specifications for aviation gasolines; the securing of necessary data for the establishment of standard flight test specifications for engines, including variations of horse power with the pressure, density and temperature of the air supplied the carburetor; the measurements of the effect of different compression ratios on engine power at different altitudes; the increase in power possible when using supercharging devices designed to supply the engine with air at pressures greater than that at which the airplane is flying.

Airplane Radiators

The necessary apparatus has been designed and constructed to study the heat transfer characteristics of radiator cores used in airplanes. The performance of more than 85 different types of cores has been studied in this apparatus at reduced pressure and high rates of air flow. Head resistance measurements have been made on these cores in the 54-inch wind tunnel. The results of these experiments have shown that certain types of cores in use today may absorb twice or three times as much of the engine power as other types and as much as 25 per cent of the total power developed by the engine.

Experiments on the head resistance of a model fuselage fitted with a nose radiator have shown that the power absorbed by the resistance of a nose radiator may be as much as 40 per cent greater than that absorbed by a radiator more suitably placed. To afford maximum efficiency, a radiator must be designed for its particular air speed and position on the airplane. The results of this investigation give the necessary data for the design or selection of radiators for all air speeds and for various locations.

Ignition Problems

Investigations have been made on various problems connected with spark plugs and other ignition apparatus used on airplane engines. This work has resulted in the development of a new porcelain for spark plug insulators which is definitely superior electrically and mechanically to any previous commercial product. Methods of test for spark plugs have been developed as a basis for Bureau of Aircraft Production specifications and several thousand spark plugs have been tested by these methods. The results have led to the use for aviation work of several high-grade commercial porcelains not previously considered for this purpose.

Carburetion

In the carburetor testing plant the work has included a detail study of the changes in mixture proportions that occur with throttle manipulation under the conditions of atmospheric pressure and temperature existing at and between ground level and 33,000 feet altitude. This work has resulted in the development of suitable control of the mixture under throttle manipulation at any level above the earth's surface; and in the development of methods and devices for automatic correction of the variations in mixture proportions ordinarily occurring in passing from ground level to an altitude of 33,000 feet.

Light Alloys

An important group of problems which engaged the attention of the Bureau was that relating to the production of light aluminum alloys and the improvement of their mechanical properties. Thus, new manufacturing methods were developed for a well-known rolling and forging alloy by which both the ease of its production was increased and its physical properties improved. Studies were made of the corrodibility of various alloys, while mechanical and metallurgical tests were made of a variety of different compositions of alloys giving most valuable information for the guidance of the designer of engines and planes.

A light alloys committee was organized to act as a clearing house for information along these lines and to oversee and direct the research work proceeding throughout the country.

Airplane Dopes and Varnishes

Specifications for acetate and nitrate dopes were prepared at the Bureau with the cooperation of dope manufacturers,

airplane constructors, and representatives of the government. Simultaneously, dopes manufactured in the country were examined in accordance with the specifications and list of products prepared which were approved for use on government aircraft. After much controversy, the use of acetate dopes containing tetrachlorethane was forbidden because of the toxicity of the above compound. Many proposed methods of fireproofing dopes and fabrics have also been examined. A commerical method of preparing and stabilizing lactic acid esters was devised for use in acetate dopes, in order to conserve the products of acetate of lime. A transparent silk fabric for possible use in obtaining low visibility has recently been perfected. Lately work has been in progress on the pigmentation of dopes with a view to protecting the dope film from the deteriorating action of sunlight, and thus prolonging its life, at the same time dispensing with the use of enamels, thus saving one step in production. The use of pigmented dopes will also conserve cellulose acetate.

Investigations of methods of making wooden parts of airplanes water resistant showed that a good grade of spar varnish was satisfactory, and a specification for such a varnish that could be produced at low cost was prepared. The same varnish has been found to be a satisfactory coating for doped linen or cotton, used either as a transparent varnish or as the basis of a vehicle for pigmented coatings. These may be used on both wood and metal.

Airplane Fabrics

Previous to 1916 linen fabric was used exclusively in the covering of airplane wings and found to be satisfactory in every respect. During the present crisis, it became evident that the available supply of linen would not suffice for the demands of the military programs of the Allies, and it became necessary to find a material which would form a satisfactory substitute for linen. The urgency was emphasized by the conditions in Russia, from which the larger portion of the flax formerly had been derived.

As early as January, 1916, the Bureau started investigating the possibilities of substituting cotton for linen airplane fabric and found that the general consensus of opinion among manufacturers and investigators here and abroad was that cotton fabric could not be used for wing coverings. Their difficulties were due to the fact that they attempted to substitute structure

of fabric rather than physical properties. The linen fiber has radically different properties from the cotton fiber, and the only hope for successful cotton airplane fabrics was so to change their structure that the ultimate fabric had the same properties as the linen fabric.

The investigation was confined to the study of stresses and stress distribution in fabrics, together with the factors covering the properties of cotton fabric as related to wing covering.

This phase of cotton manufacturing was an entirely new one, and great difficulty was experienced in studying the manufacture from a new angle, on account of the limited time available. Upon the entrance of this country into the war all the facilities of the manufacturers were made available to the Bureau's experts.

In March, 1917, the Bureau was in a position to issue instructions covering the construction of cotton fabrics, some of which proved quite successful. The next important step was to determine the actual performance of these fabrics and to this end samples were placed on Army planes at Langley Field and Navy planes at Pensacola during August, 1917. Later these fabrics were placed on planes manufactured by the Canadian Aeroplane Company of Toronto about the middle of October, 1917, in all cases with the most satisfactory results.

The Grade A cotton fabric now being supplied to the Air Service compares favorably with the linen regarding weight, has a much higher factor of safety, a greater tear resistance, and dopes up to satisfactory tautness. The life of any fabric is dependent entirely upon the life of the dope, and therefore the cotton has as long a life as the linen.

The English Government became concerned about its linen supply, and also adopted the fabrics designed by the Bureau.

As a result of more recent investigations by the Bureau of Standards, another distinct fabric has been evolved which is 25 per cent lighter than any linen fabric now in use, and is materially stronger.

Director S. W. Stratton has placed the services of the entire Bureau of Standard's staff at all times at the disposal of the Air Services of both the Army and Navy in attacking and solving new problems which have constantly been presented, and in fact the Bureau has been during the war practically an adjunct of the War and Navy Departments.

LEONING MONOPLANE—300 H. P. HISPANA-SUIZA ENGINE [SQUIER]

IX—National Advisory Committee for Aeronautics

THE National Advisory Committee for Aeronautics was established by Congress by Act approved March 3, 1915. Under the law the Committee is charged with the supervision and direction of the scientific study of the problems of flight with a view to their practical solution, the determination of the problems which should be experimentally attacked, their investigation and application to practical questions of aeronautics. The Committee is also authorized to direct and conduct research and experiment in aeronautics in such laboratory or laboratories, in whole or in part, as may be placed under its direction.

In addition to its specific duties, the Committee has acted as a clearing house for inventions submitted to the War and Navy Departments with a view to their possible usefulness in the field of aeronautics. These inventions have been studied carefully by the Committee's technical staff and those deemed worthy of development have been called to the attention of the Military branches of the Government. During the last year, the Committee has examined approximately seven thousand such inventions and suggestions.

The Committee is recognized by the Aircraft industry as an authoritative source of technical information and as a court of arbitration whose weighed judgment obtains. The National Advisory Committee for Aeronautics is today the only official agency for the development of aeronautics which numbers among its members officers of both the Army and the Navy thus assisting in the coordination of the air activities of these services.

The scope of activity for aeronautical research to be carried out by the Committee in the future has been outlined to include the following investigations:

1. Propellers; 2. Aerofoils, or elementary supporting and controlling surfaces; 3. Combinations of supporting and controlling surfaces; 4. Reaction between the airplane and the propeller system; 5. Structure; 6. Investigations to improve the present instruments for use in airplanes and to develop new instruments to meet future needs; 7. In connection with aviation engines, the problem of supercharging to maintain power at different altitudes; 8. Improvement of engine details, radiation, carburetors, ignition, and fuels and lubricants;

9. Standardization and investigation of materials for aircraft construction; 10. Free flight tests; 11. The study of the relation of the atmosphere to aeronautics.

Some of the more important reports rendered during the last year are:

1. Behavior of Airplanes in Gusts. 2. General Theory of the Blade Screw. 3. The Testing of Balloon Fabrics. 4. Aluminum and its Light Alloys. 5. Carbureting Conditions Characteristic of Aircraft Engines. 6. General Analysis of Airplane Radiator Problems. 7. Effect of Compression Ratio, Pressure, Temperature, and Humidity on Power. 8. Properties and Preparation of Ceramic Insulators for Spark Plugs. 9. Heat Energy of Various Ignition Sparks. 10. A New Process for the Production of Aircraft Engine Fuels.

With the completion of the Committee's aeronautical laboratory at Langley Field, the Army Experimental Air Station, the work of aeronautical research will be expanded, it is hoped, to cover present and future problems vital to the Science and Art of Aeronautics.

The National Advisory Committee for Aeronautics gave valuable service to the Army and Navy both before and especially during the early months of the war. This body of selected men, reporting directly to the Congress, furnished to the Chief Signal Officer a medium for counsel and advice. This Committee inaugurated and recommended the establishment of the Aircraft Board. Prior to the establishment of the Aircraft Board, the Chief Signal Officer enjoyed the counsel of the Advisory Committee which was always ready to assemble without regard to time or place.

Although the statute creating this Committee contemplated a general supervision of aeronautical research, all manner of questions were submitted to its deliberation and judgment during the early period of the war. Whether it was the founding of a permanent aeronautical experimental station which should be a sort of West Point for aeronautics, the assembling of University Presidents to establish curricula for our ground schools, or the search for a practical solution to the stifling situation confronting the Government as a result of the airplane patent controversy, the National Advisory Committee was at all times available to the Army and Navy authorities for counsel and decisions.

X—Work of the Science and Research Division of the Signal Corps

THE Science and Research Division of the Signal Corps was established by order of the Chief Signal Officer on October 22, 1917, and Lieut. Colonel R. A. Millikan placed at its head.

Its personnel, exclusive of the Meteorological Section, consisted on November 11, 1918, of twenty-one commissioned officers, 118 enlisted men, and sixteen civilian employes of scientific and technical qualifications. Four of these officers are abroad and seventeen in the United States.

At the time of the signing of the armistice, the Science and Research Division had in progress sixty-four problems.

A summary of the most important results actually achieved up to that time is given herewith:

1. The Aeronautic Instruments Section, in addition to fulfilling the function specifically assigned to it of writing all the initial specifications for aeronautical instruments in use on planes, and in working continually with the instruments in production in order to detect imperfections and make suggestions for improvement, designed and developed wholly within its organization, through the activity of its chief, Major C. E. Mendenhall, a new and improved Pitot-Venturi tube for use in the determinations of airplane air speed. This instrument was actually put into production and thirty-seven thousand ordered.

2. Major Mendenhall and Lieut. R. C. Williamson have cooperated with the General Electric Company in the development of a new and improved compass, ten thousand of which were produced. This compass is now in use on planes for the American Army.

3. The Science & Research Division cooperated with the Eastman Kodak Company in the development of an entirely new film camera which is in production and which is the only film camera in existence capable of taking the standard size 18 by 24-cm. pictures. This camera is entirely automatic and capable of taking one hundred pictures without refilling.

4. The Science and Research Division with the assistance of the Burke & James Company of Chicago developed a new plate camera which is a modification of the French De Ram. It is

semi-automatic, carrying fifty plates. It has been accepted and is in production now. Both this photographic development and the one mentioned under (3) were made possible solely by the bringing together of a highly trained scientific group in the Photographic Section of the Science & Research Division. There would have been practically no possibility of the attainment of these results without such a group. This photographic group constituted one of the Sections of the Science & Research Division until about July 1, 1918, when it was transferred to the Production Division. The development of photography during the present war, due to the advent of the airplane has placed it permanently among the indispensable agencies for successful military operations. The older methods of recording personal observations have been superseded entirely by the far more accurate and reliable photographic record. A complete detailed photographic map must now be made daily of each sector immediately in front of an army, and by carefully matching these maps and by intensive study of each individual area, the maze of trenches, entanglements, machine-gun nests and shell-holes can be accurately analyzed. It is worthy of notice that 17,000 photographs were taken by the British army before the operations at St. Quentin in order that a relief map of the sector might be made before the drive against the Germans. By means of this map, every detail of the work to be performed by the British troops was planned. By a series of consecutive photographs taken at regular intervals by a moving-picture camera an accurate and reliable picture of a military road, for instance, showing all details to scale may now be made in a few minutes. With the aid of the camera the detection of camouflage is possible where the human eye would fail. This highly specialized photographic work has now taken its permanent place in the waging of modern warfare.

5. Dr. Gordon S. Fulcher, working in collaboration with the Miller Rubber Company, developed a leak proof tank simultaneously with the development of a similar tank in England—achievements of the utmost importance for the lives of Allied aviators. The Fulcher Tank was ordered placed upon all fighting planes.

6. Major C. E. Mendenhall and Lieut. John T. Tate, with the assistance of the General Electric Company, perfected a trench signalling lamp which, after test at the front, was

ordered sent over in considerable numbers and will probably constitute a standard American projector for the United States Army.

7. Major R. W. Wood developed a telescopic signaling device using a six-volt, two-ampere lamp. This lamp was tested at the front and favorably passed upon by the A.E.F. It has made possible light signaling in broad daylight over a distance of eighteen miles. General Pershing ordered a considerable number of these sent to the A.E.F.

8. Major Wood also developed a secret daylight signaling lamp which has a range of five miles. This also was ready for shipment abroad at the time of the signing of the armistice.

9. Secret signaling at night, with the aid of ultra-violet light, was perfected by this department, working in collaboration with Mr. Norman Marshall. With simple signaling telescopes of the sort mentioned above, using only a six-volt, two-ampere lamp, secret signals have easily been sent six miles. Major Wood also developed new means of adapting this method to the problems of signaling to airplanes, and secret signaling between convoys, and obtained thereby a device which will be of much use in peace as well as in war.

10. W. J. Lester, S. R. Williams, Capt B. J. Sherry and Sergt. W. H. Redman of this Department developed propaganda balloons which have a range of more than a thousand miles. This is an accomplishment which is invaluable to the future development of aviation, particularly with reference to transatlantic flights, whether in peace or in war.

11. Dr. W. F. G. Swann and Dr. Gordon S. Fulcher of the Science and Research Division gave invaluable service to the Balloon Section by making an elaborate and highly important study of the causes of fires in balloons and sending to the balloon officers in the Balloon Section directions for the prevention of such fires.

12. Dr. H. N. Russell of the Science and Research Division and Capt. J. P. Ault developed means for navigating airplanes with the aid of the sextant and an artificial horizon. They also developed means of speedy reduction of observations so that an observer in a plane can locate himself with an average error of not more than ten nautical miles within five minutes after he makes his observation. This achievement is of great value for the problem of long flights.

13. Lieut. John T. Tate and Otto Mohr developed a port-

able landing light for use on aviation fields. This device was officially tested and favorably reported upon by the division of Military Aeronautics. It is now in use at some fields and recommendation has been made by the Division of Military Aeronautics that two complete units be made a part of the permanent equipment of all aviation fields.

14. Dr. Harvey N. Davis of this Division represented the army in the development of the helium program and contributed in a large measure to the great success which has been attained in that work.

15. The Chemical Section under Dr. H. D. Gibbs developed new methods of producing acetone, which will make it possible to obtain this substance for one-fourth the price which the Government is now paying.

16. The Chemical Section, through the activity and energy of Dr. L. E. Wise, developed sensitizing dyes which previously had not been obtainable at all in the United States and which were urgently needed in airplane photography.

17. Capt. Herbert E. Ives and Dr. F. A. Saunders of this Department, in collaboration with I. W. Priest of the Bureau of Standards, made notable contributions in the development of color filters for detecting camouflage and increasing visibility. Forty thousand of these devices now are in use in the Army and Navy.

18. Dr. Wilmer A. Duff's Section worked out the only method which has been developed thus far for the accurate, experimental determination of bomb-trajectories. This is of primary importance in obtaining precision in bombing. It will have peace uses as well as war uses.

19. Dr. Duff's section also developed a bombsight stabilizer which has reduced the main error now made in bombing, namely, the error in the determination of the vertical, by more than three-fold. When it is remembered that a three-fold increase in the accuracy of bombing is precisely equivalent to the multiplication by three of the production of bombing planes, the importance of work of this kind scarcely needs comment.

There are probably a dozen of the nineteen developments mentioned above, each one of which is worth more to this country than the total amount spent upon the establishment and maintenance of the Science and Research Division from its inception up to the present time.

XI—Radio Development Work

IN the question of the engineering achievements of the Signal Corps during the war, the development of radio apparatus forms a large part. Inasmuch as the vacuum tube occupies so prominent a role in almost every kind of radio apparatus, an outline of its development logically precedes discussion of the radio sets.

Vacuum Tubes

The application to radio inter-communication of the vacuum tube—perhaps more properly called the thermionic tube or bulb—is one of the most interesting developments in the whole field of applied science. For not only has it made possible what has been justly heralded as one of the most spectacular achievements of the whole war—the airplane radiophone—but the confidence growing out of the extensive experience with the vacuum tube in warfare, coupled with its extreme adaptability, have resulted in a rapidly increasing amount of radio development involving its use.

Pre-War History

The vacuum tube was known in various forms before the war. Following extensive experiments with the so-called "Edison effect", Fleming, some years ago, produced the well known Fleming valve—a current rectifying device, capable therefore of being used as a detector of radio signals. This device contains two elements: an incandescent filament emitting electrons, and a plate upon which an alternating voltage is impressed, both placed within an evacuated bulb. Later Dr. Lee DeForest introduced an important modification by placing a wire mesh or "grid" between the filament and the plate. A small voltage variation on this grid produces the same current change through the tube as would a much larger voltage variation on the plate, thus adding amplifying properties to the detector characteristics of the Fleming valve. DeForest called his device the "audion". Later, with superior facilities for evacuation available and with a more intimate knowledge of the laws of thermionic emission from hot bodies, improvements and modifications were made in the audion or vacuum tube by both the General Electric Company and the Western Electric

Company, the latter designating their product as "vacuum tube", and the former the "pliotron".

In addition to acting as detectors and amplifiers, as mentioned above, vacuum tubes can function in two other important ways:

1. As Oscillators. In properly designed circuits containing inductance and capacity they will act as radio frequency generators, for use in transmitting or receiving radio signals.

2. As Modulators. By suitable connection to an oscillator circuit or antenna, they can be made to vary the power radiated so that the envelopes of the waves transmitted shall have any desired wave form, as for example, the speech waves from an ordinary telephone transmitter.

The most striking use made of vacuum tubes prior to the time we entered the war was the transmission of speech by radio from Washington to Paris and Honolulu, during the experiments carried out by the American Telephone and Telegraph Company and the Navy Department. Vacuum tubes were used as the radio frequency generator for transmitting, and for detector and amplifier in receiving.

When the United States entered the war, vacuum tubes already were in use by the Allied forces for various signaling purposes. The French particularly had been quick to recognize the military value of vacuum tubes and had, previous to June, 1917, developed very creditable tubes and apparatus. In America, tubes were in limited use as "repeaters" on telephone lines, and as detectors and amplifiers in laboratories and radio stations. The total production, however, in this country did not exceed three or four hundred a week.

Developments During the War

Early in our participation in the war, it became evident that vacuum tubes would be required in very large quantities in order to meet the growing demands for radio communication and signaling. It was equally evident that service conditions, not hitherto anticipated, would require great mechanical strength, freedom from disturbance under extreme vibration, and uniformity of product sufficient to make possible absolute interchangeability of the tubes in sets, without the necessity of readjusting when changing tubes. To these conditions must be added that of minimum size consistent with dependable operation.

To make such a device, with its complicated, yet accurately

MARTIN BOMBING PLANE—TWO LIBERTY ENGINES

[SQUIER]

constructed metallic system, within a practically perfect vaccum, is no small problem even when made in the laboratory, on the individual unit basis, by a skilled operator who appreciates the delicacy of the job. To turn out tubes by the thousands by factory methods involves almost infinitely greater difficulties. How well certain companies, in collaboration with the Signal Corps, have succeeded in solving these difficulties is indicated by the fact that recently the total rate of production in the United States of high quality standardized tubes was considerably in excess of one million a year. This rate of production could be made many times greater on short notice.

As an example of the difficulties which this quantity production has involved may be mentioned that of evacuation. The degree of vacuum required is such that unusual methods of exhaust are necessary. The heating of the tubes in electric ovens is supplemented by heating of the elements of the tube by excessive filament and plate electrical power input. Molecular pumps are employed, necessitating an extremely large number of pumps to handle quantity production. Special treatment of metal parts prior to assembly is employed to reduce the gas given off by them during the exhaust process.

Another problem is that of making the complicated metallic structure of all tubes exactly alike, in order to insure identical electrical properties. As an indication of progress in this direction, it may be stated that one company is prepared to manufacture, in quantity, a certain tube in which the clearance between filament and grid is only three hundredths of an inch, the allowable variation being of course only a small percentage of this.

Manufacturing in quantity involves careful inspection. The problem of specifying definitely the required performance of tubes, the development of adequate testing specifications, the placing of standardized testing and inspection methods, personnel, and equipment in the various factories so that tubes manufactured at different times and places would, after passing inspection, be uniform and interchangeable—these questions were entirely new and have been solved almost entirely by the Signal Corps Engineers.

Present State of the Art

Tubes developed by the Signal Corps may be divided into two general classes: the tungsten filament types as developed

and manufactured by the General Electric Company and the De Forest Radio Telephone and Telegraph Company, and the coated filament or Wehnelt Cathode types as developed and manufactured by the Western Electric Company. The coated filament tubes so far have proven superior to the tungsten filament tubes for Signal Corps use. Both classes have been standardized as regards base, exterior dimensions, filament current and voltage, and in addition, plate voltage and output for transmitting tubes; and amplifying power and detecting power for receiving tubes. Except in certain special cases, the Signal Corps uses two types of tubes, one for transmitting, and another for receiving. The French and the British have been using one type for both transmitting and receiving, but present tendencies of the British are toward different tubes for different duties.

Vacuum tubes are now employed for electric wave detection, radio frequency and audio frequency amplification, radio telephony, particularly in the airplane radiophone, continuous wave radio telegraphy, voltage and current regulators on generators, and for other miscellaneous purposes. However, varied as are the applications at present, the uses, actual and potential, growing out of war development work have proved that the art of Vaccum Tube Engineering, and the application of its products to radio engineering, telephone and telegraph engineering, and particularly to electrical engineering in general, are still in their early infancy. That vacuum tubes in various forms and sizes will, within a few years, become widely used in every field of electrical development and application is not to be denied.

The engineering advancement accomplished in less than two years represents at least a decade under the normal conditions of peace, and our profession will, it is hoped, profit by this particular salvage of war which offers perhaps the most striking example extant of a minimum "time-lag" between the advanced "firing line" of so-called pure physics, and applied engineering.

The Chief Signal Officer considers that the work of standardization and quantity production of vacuum tubes accomplished during the last eighteen months under the pressure of military necessity, represents an advance in the art of electrical engineering which will prove of inestimable industrial and scientific value to this country, and to the engineering world at large.

Airplane Radio Telephone Set

Prior to April, 1917, a few experiments had been made, in which speech had been transmitted from airplane to ground by radio methods; but the apparatus involved was hopelessly crude. On May 22, 1917, the Chief Signal Officer called a conference in his office at which the project of evolving a "voice command" equipment for airplanes, which should meet all the severe requirements of the military service, and which should be thoroughly standardized for quantity production, was definitely set in motion against time. The plan for accomplishing this was the same as in the evolution of the Liberty engine, and from the beginning this project was regarded as one of the major creative efforts in the development of the American Air Service. The present airplane radiophone, therefore, is the result of a period of intensive development work began shortly after we entered the war. The services of the Western Electric engineers were enlisted, and under the direction of the Signal Corps, rapid development resulted in successful tests as early as August, 1917. Speech was exchanged between airplanes twenty-five miles apart in October, and sample sets were sent at once to the Army in France for trial. Several thousands sets were ordered and have been completed and distributed to flying fields here and to the Air Service in France.

The satisfactory performance of this apparatus has resulted in a new type of military unit known as a voice-commanded squadron. The commander of an air fleet directs the movements of the individual units in any manner desired; the effectiveness of the squadron as a military machine is thereby enormously increased.

Other uses are in communicating information from airplanes to ground stations, and in directing one or more airplanes from a ground station. Innumerable applications will be evolved as the possibilities are realized.

The essential elements of the Airplane Radiophone are the power equipment, the radio equipment, and the antenna.

a. The power equipment includes a double-voltage direct-current generator driven by an air fan, with a vacuum-tube voltage regulator.

b. The radio equipment consists of the vacuum tube transmitting and receiving set, and the special telephone transmitters and receivers. Those of you who have heard the terrific roar of a Liberty engine will realize the difficulty of talking in an airplane in flight. The development of a transmitter which is affected by the human voice, and not by the enormously greater engine and wind noises, is one of

the principal features of this set. Similarly, to shield the ears of the aviator from the same noises required a special combination of sound-insulating materials surrounding the telephone receivers and suitable for use within an aviator's helmet.

c. The antenna originally consisted of a flexible copper wire several hundred feet long, unreeled by the aviator and trailing almost horizontally behind the airplane. Modified antenna using much shorter wires fixed to the framework are now used.

The operation of the sets is extremely simple, all adjustments being made before leaving the ground. The only manipulation required of the aviator is that of the change-over switch to change from talking to listening.

Airplane Radio Telegraph Set

The principal use of radio communication made during the war was in sending radio telegraph signals from observation airplaines, for controlling artillery fire. The French developed a set which consisted of several units, making the installation and operation complicated. The Signal Corps developed a self-contained set, which has been demonstrated to be far superior to any other airplane set.

It consists of three units—first, the 200-watt, 900-cycle alternator, driven by a regulating air fan, and containing in a stream line case attached to the generator, all the elements of the radio set. This radio apparatus is of the synchronous spark type, with four spark tones and nine wave lengths. The weight of the complete unit is only twenty three pounds, and size only six inches by six inches by twenty-six inches. The regulating air fan maintains the speed of the generator within four per cent of 4500 rev. per min., with air velocities between 60 and 200 miles an hour.

The remaining units in the complete set are a variometer or tuning coil, with antenna ammeter attached, and the antenna system, comprising a reel, insulated bushing, and training antenna. When it is realized that voltages of thirty thousand or more are produced by this set, the difficulties of insulation in such restricted spaces will be appreciated.

Ranges of communication of one hundred miles have been accomplished with this set.

Airplane Direction Finder

One of the principal problems of airplane navigation has been the evolution of a suitable compass, particularly for night bombing work. Magnetic and gyroscopic compasses have

limitations at present which make impossible reliable air navigation by dead reckoning.

The use of directional effects of loops or coils for receiving radio signals have resulted in the development of a radio compass for airplanes which gives positive information to the aerial navigator, and enables him either to locate his position by triangulation with respect to two beacon land stations, or to fly at any given angle with respect to a certain beacon station.

The apparatus consists of two principal parts—the antenna coils, and the tuning and amplifying apparatus. The antenna coils are mounted in the fuselage of the Handley-Page airplane, with suitable means for rotating in azimuth. The amplifier is extremely sensitive, consisting of a detector and six-stage amplifier. A novel feature of the amplifier is the use of iron-core transformers for frequencies of 100,000 cycles.

The direction of the beacon land radio station is determined by maximum strength of signals, in a highly ingenious manner developed originally by the British. The precission of the directional effect is remarkable. In fact the radio direction finder may well be called a radio eye, by which the aerial navigator sees one or more radio lighthouses which are sending identifying signals to guide him on this way. These lighthouses, furthermore, have certain advantages over the normal light-house in that their ranges may be much greater, and they are not invisible in the day time nor obscured by fog and mist.

The remarkable advances made during the last eighteen months have resulted in the application of radio communication to practically every phase of military aviation. Commercial and military possibilities have, however, hardly been touched as yet. It is believed that radio apparatus soon will be as essential on aircraft as it now is on ocean going steamships, and that its use will enormously increase the effectiveness of aircraft for all purposes.

XII—The Liberty Aircraft Engine

Foreword

AS we look back on the record of accomplishment in the problem of obtaining large numbers of high powered aviation engines for our Army and Navy Air Services both in this country and abroad, it seems to those of us who were in close contact with the work and the difficulties more like a fairy tale than the statement of hard facts which it is in reality. On the face of things, it certainly would seem to be the height of presumption to assume that this country could, following its almost total neglect of aviation development in previous years, hope to design, develop and produce in unprecedented quantities an acceptable aircraft engine of greater power than had yet been evolved by any of the European nations, even under their spurs of governmental encouragement and tremendous war demands. Yet just that and nothing else was the only thing to do, and the story of its doing is one of the most brilliant chapters in the history of our Country's part in the Great War.

Initial Situation

At the time this country entered the war, in April 1917, there were being built in the United States only four makes of engines that were developed so far as to be considered of any military value, and even these were useful only for primary training. We had no engines at all suitable for services on the battle front, or even for the advanced training of pilots. The largest engine of domestic manufacture developed about 220 horse power and had not proved satisfactory when judged from the standpoint of combat service requirements. The others ranged in power from 90 h. p. to 135 h. p. It, therefore, was evident that the existing American engines could be used for preliminary instruction purposes only, and that their further manufacture should be limited to the training requirements. This was done, with the result that by far the greater portion of the primary training of pilots has been conducted with the Curtis OX-5 90-h. p. engine, the quantity production of which was early obtained. This engine was particularly valuable, owing to the very satisfactory training plane which had been designed around it. The Hall-Scott A7-A 100-h. p. engine

was also extensively used at first until the production of the Curtiss engine could be brought to a point to meet all demands for primary training.

Two European engines, the Gnome 100-h. p. and the Hispano-Suiza 150-h. p., were being put into production in this country early in 1917, by the General Vehicle Company and the Wright-Martin Aircraft Corporation respectively. These concerns had obtained contracts with Great Britain and France, but were experiencing considerable difficulty in getting production under way. The production of the first Gnome engine was not completed until a period of more than nine months had elapsed, during all of which time English experts were present in the contractor's plant and aiding the manufacture. In the case of the Hispano-Suiza, notwithstanding the assistance of a group of French experts sent over to help get it into production in the minimum time, thirteen months were required to get the first production engine on the test block, and another month before the first delivery was made. Preparation periods were filled with the most costly experiments and the development of methods and tools for performing the intricate operations required by the design of these engines. All of which expense and delay had cost our Allies dearly.

The Gnome and Hispano-Suiza engines represented the highest product of European design and were in a perfected and standardized state, according to foreign practise and conditions, when their production was undertaken in this country. Nevertheless, the changes involved in adapting them to manufacture by American methods, and the development of expert workers for those operations which could not readily be so adapted, required so much time that the advances made in aeronautical engineering rendered such engines largely obsolete for service at the front, by the time they could be produced in sufficient numbers to supply any material portion of the requirements.

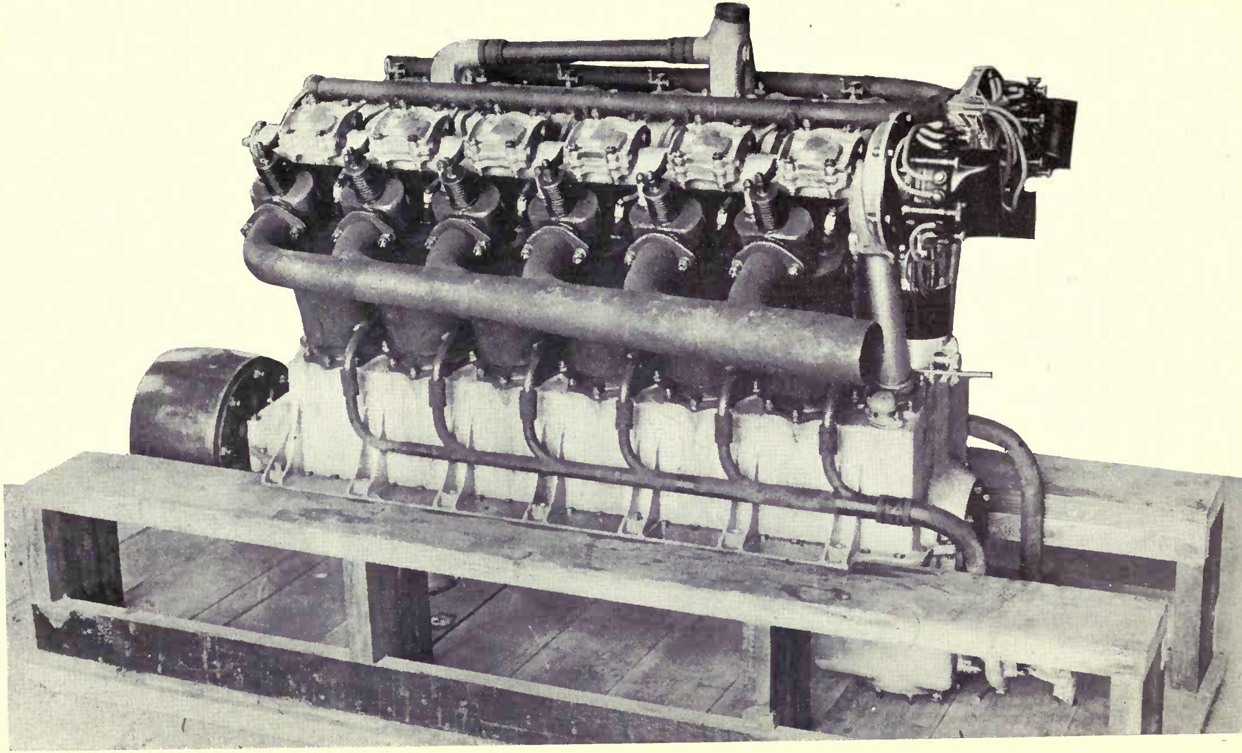
These two engines were, however, of unquestioned value for advanced training purposes, the Hispano-Suiza in particular being a dominant factor in this work. Later the Le Rhone 80-h. p. was put into production by the Union Switch & Signal Company and, by proper utilization of the lessons learned in the case of the other two foreign engines, reasonably satisfactory progress was made in manufacture. This engine, too, was used for advanced training work.

Liberty Engine Inception and Experimental Development

One of the serious mistakes which the Allies had fallen into at the time the United States entered the war was the development of a multiplicity of types of engines and planes which made it impossible to have a large number of any one of these types. As a further consequence, the trained personnel on the ground to operate and repair the machines had grown to such a proportion that it was estimated that from thirty to fifty men were required on the ground to keep each one of the many types of planes in the air on the fighting line. Manifestly, unless this large number of trained men per fighting plane could be reduced by some means it would be hopeless to expect within a reasonable time to put into the air thousands of flying planes, because a single thousand planes on this basis would require from 30,000 to 50,000 men in attendance.

The experience obtained in getting two foreign engines into production in this country and under our manufacturing methods, so thoroughly demonstrated the futility of attempting any such solution of our service engine problem as to at once eliminate its continued consideration. It was realized that copies of foreign designs could not be available in time and in adequate size or numbers to answer the demand for an overwhelming air force at the front. American air performance would have been very small indeed if limited by such a handicap as this.

Moreover, in spite of the fact that a technical commission was at once organized and despatched for the purpose of getting first hand information on the front and in the aircraft centers of Europe, it was unthinkable that this country should sit idly by and wait perhaps months for the final definite report which should decide the nature and extent of our part in the Allied aircraft program. Since the most successful airplanes are designed around specific engines, and the engine involves the greatest expenditure of time and effort in development, it was apparent to a few of us who were in close contact with the situation that it would in all likelihood be possible to design, develop and produce an entirely new American engine, embodying characteristics which would render it particularly adapted to manufacture under American conditions, in less time than would be required by the commission to determine the particular European engines that offered the best approximation to the various exacting requirements of service and



LIBERTY ENGINE—12 CYLINDERS

[SQUIER]

production, plus the time to get it in production in this country. It was decided, therefore, that our efforts should be directed along both these channels simultaneously and in addition to purchase in Europe whatever service equipment might be available, to tide over the interval while we were getting into production.

It is apparent that the fundamental unit of engine design or construction is the cylinder, and that the evolution of engine power rested mainly with the unit power capacity of that cylinder which could be taken as representing the largest practicable size sanctioned by the state of the art at that time. Starting with the foundation of this cylinder then, it was the most direct reasoning to conclude that all requirements of the service for engines of varying power capacities could be most logically met by combining these unit cylinders into groups of whatever number were required to produce the several sizes of engines desired. This was done, and the cylinder size of five inches bore by seven inches stroke was selected, after a careful examination of the performance of both American and European engines of the then most modern design, as being the largest that could be relied upon to give satisfactory service. While originally designed to produce approximately 28 h. p., this cylinder has been so developed as to yield at present more than 40 h. p. as the result of somewhat increasing the speed and altering the functioning characteristics. The standard unit cylinders were to be used in engines having four or more cylinders each and yielding the following power output:

Number of Cylinders.	Original Rated h.p.
4	110
6	165
8	225
12	335

Thus, for the first time in the history of the aeronautic engine for military uses, a truly comprehensive design plan was evolved which in a simple and direct manner provided for the production of a whole line of engines of wide power capacities, but composed of units that were highly standardized and therefore could be really manufactured, instead of being merely built. This was, and is, the only way in which this country

could meet the requirements of this most vital part of the program.

It must not be thought, however, that such a revolutionary decision was easy to make, or adhere to when made, in the face of all kinds of adverse criticism, some of which seemed to be based upon adequate grounds. The development of new types of aircraft engines heretofore had been such a time-consuming matter that it was generally regarded as a thing to be avoided if any ready-developed engine could be found anywhere which would at all answer the requirements. Thus the numerical preponderance of opinion was against the possibility of a standardized American engine being designed, developed, and produced in large numbers, in anything like as short a time as would be required to duplicate some European engine. The nation may well render thanks that its destinies in this particular were guided by such a far-seeing and courageous group of men, who had the ability to formulate such plans and then to enforce their realization.

You are all familiar to some extent with the history of the design and construction of this engine:—how Lieutenant Colonels J. G. Vincent, of the Packard Co., and E. J. Hall, of the Hall-Scott Motor Car Co., laid down the general features and got out the first assembly drawings personally between mid-day of May 29 and the afternoon of May 31, 1917, working in Col. E. A. Deed's apartment in a Washington hotel in response to a request for a report on the aircraft engine situation, which came from Howard E. Coffin, Chairman of the Aircraft Production Board; the Chief Signal Officer of the Army; Colonel Edward A. Deeds, Chief of the Equipment Division, Signal Corps, and Colonel Sidney D. Waldon, Assistant Chief:—how the order to build ten sample eights and twelves was given as the result of the approval by the joint conference of the Army and Navy Technical Board and the Aircraft Production Board:—how the first engine, an eight-cylinder, was built in one month as a result of the enthusiastic cooperation of some ten manufacturers, each of whom produced those parts for which they were best fitted:—how the first sample twelve-cylinder finished its official fifty-hour endurance test eighty-two days from the time the order for samples was given, and that the total elapsed time during this test was only about fifty five hours, a record-breaking performance:—and how the success of this endurance test definitely removed the engine from the experimental stage to the realm of proved engines.

A very gratifying endorsement of this standardized engine project came from the late Colonel R. C. Bolling, whose untimely death in France cost the American Air Service one of its most valuable officers, and Col. V. E. Clark, and Lieut. Col. Howard C. Marmon, members of the commission sent abroad to ascertain the requirements, and which returned about this time, to the effect that a 400 h. p. engine was absolutely demanded at the front for the types of airplanes which it had been decided this country should supply, and that no engine of this size then existed in Europe.

Those of us who are familiar with the difficulties and disappointments involved in the design, development and perfection of any form of intricate mechanical device can readily appreciate the really remarkable accomplishment represented in the Liberty. Therefore, it is not at all surprising that the representatives of the Allies were for some time unable to believe the full truth of this accomplishment. They never had been able to obtain such action and were, naturally, only fully convinced after many varied and exhaustive tests. So well recognized did the value of the Liberty engine become, however, that the Allies had on order at the time of signing the armistice 16,741 Liberty engines, and were constantly endeavoring each to increase their rate of monthly delivery. Airplanes were being designed around this engine in all Allied countries and it was fast becoming the predominating aeronautical engine of the Allied cause.

It is of interest in this connection to note that this standardized engine already has been tested in the twenty-four cylinder model, and shown results which prove that the original basic idea will provide for engines of any size which would have been required for any probable increase in airplane size during years of continuation of the war. The sixteen cylinder was also proved by the success of the larger engine.

The experimental development of the Liberty has been in charge of a department entirely separate from that dealing with its production, the Airplane Engineering Department under Lieut. Col. J. C. Vincent and Lieut. Col. Howard C. Marmon. The work of this department has resulted in a continuous improvement of the power output and performance characteristics of the Liberty twelve cylinder, to such an extent that 526 h. p. have been obtained with special fuel and detail changes; certainly a remarkable increase from the

335 h. p. which the original design was intended to yield. While the weight of the service engine per horse power has remained at approximately two pounds, the maximum present development had reduced this figure to one and two thirds pounds.

Liberty Production—Development and Production

The record of production and production-development of the Liberty conclusively proves the wisdom of the decision to concentrate all efforts on this one engine for the major part of our program of combat engines. In common with all similar machines, many possible improvements and cost reductions become evident as the manufacturing processes and tools are being evolved and as experience is being acquired in the actual production. Also, experience in the operating and adjustment of these engines led to alterations being made which resulted in increasing the power output; so that when we were advised that more power was desired than the 335 h. p. which the original Liberty was designed to produce, the necessary steps already were known and the delay incidental to putting them into effect was small. The resulting power increase to about 375 h. p. answered requirements for several months when advices were again received that more power was needed, and we then again made such alterations as were required to increase the power to around 420 h. p. The weight of some of the parts was increased at this time in order that the reliability might not be reduced.

The problem of production was placed in the hands of a separate department in charge of Lieut. H. H. Emmons, U.S.N., and the continuous assistance of such men as Henry M. Leland, of the Lincoln Motors Co.; C. Harold Wills, of the Ford Motor Co.; F. F. Beall, O. E. Hunt and Edward Roberts, all of the Packard Motor Co., were obtained by Major J. G. Heaslet, in charge of the Detroit district. The work of Mr. Wills which has the greatest value was the perfection of a new process for the forging of cylinder blanks in sufficient quantities to supply all manufacturers, and which was so very effective that the problem of cylinder forging supply and cost was reduced to a minor consideration. The wisdom of the action taken is evidenced by the production of 1100 Liberty 12s in one year from the day when Messrs. Vincent and Hall first met and started a preliminary drawing, and over 15,000 by the end of another six months.

It is perhaps to be expected that many criticisms would be leveled at an engine evolved under the conditions obtaining at that time, and registering the large success which it represents, but all such have proved to be the result of misinformation regarding the conditions to be met, the fundamental ideas of design, or of lack of appreciation of the difficulties encountered in creating at a single stroke and without previous experience, an aeronautical power plant so much larger than was then in existence.

The Liberty engine stands today as an achievement which for daring, constructive imagination and farsightedness will ever be a cause of pride to the American people.

XIII—A Granular Theory of Armies

IN these days we are face to face with the so-called granular theory of electricity and matter, whose fundamental unit is the electron. From one angle of view, as I shall hope to show, there is also a granular theory of armies.

The history of the military operations of the past disclose the fact that the actual combatant troops are specially selected men most fit physically for the hardships of war. In general terms the actual fighting has been restricted to selected persons from the male population with definite maximum and minimum limits for age and also definite requirements for the vital physical functions.

In the language of the physicist we may say that the male population of a nation is carefully segregated by a sort of "band filter" which picks out for combatant warfare only those whose age cycles fall between say eighteen and thirty years. These selected men are then brought to a further common standard by intensive physical training before they are permitted actual combatant service. This elevation of the military unit to a common physical standard makes possible, as will be readily seen, the formation of larger units such as companies, battalions, brigades, divisions, corps and armies and their direction by a centralized command in the tactics of war.

Invoking the law of averages, we may say furthermore that,—*the one unchanging factor in warfare is the individual physical strength of a man.*

The soldiers of Ceasar's army were physically no stronger nor weaker than our own. On the average, a battalion or company of soldiers from one nation can march, for instance, just as far in a day as a battalion or company from any other nation, and this statement was equally true before the Christian era, and is not likely to change in the future.

In consequence of this fact, military supremacy must be looked for primarily in the weapons and agencies provided by scientists and engineers and placed in the hands of these combatant units to multiply their military strength.

To illustrate, the day in the fourteenth century, when Berthold Schwartz or whoever actually invented gunpowder, put together charcoal, sulphur and saltpeter, he, by a scientific

act, and at a single stroke, exerted more influence upon the development of warfare and indeed the history of the world since that time, than many armies could accomplish by any mere physical qualities which they possessed.

Stated in another way, if our enemies in the recent great conflict had been made up wholly of civilizations like those of Turkey and Bulgaria, nearly all of the agencies which I have been describing during the past hour would have been utterly impossible of either development or production by them. There were no Liberty engines nor airplane radio sets evolved or made in this quarter, nor could there be such without outside aid.

It follows from this, that those civilizations which by their scientific and engineering training can create and manufacture these agencies, will and must control the fortunes of war in the future, or far better, apply these same agencies, in a potential way, to banish war from the world for all time.

The present war has made aviation in four years what it would have taken two decades at least to accomplish in times of peace, and has multiplied the reach and capabilities of the physical military unit to an extent which is only now in the beginning. May we not fervently hope that the further development of aerial navigation will place in our hands such potential destructive powers as to go a long way toward making war impossible again?

I can say no more at the present time.

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IN conclusion, the courteous invitation of the Board of Directors of this Institute to address you on this occasion, suggested that I may have some message to deliver to the American Engineer.

The organization of the American Air Service requiring, *inter alia*, the foundation of a new industry under the adverse conditions above outlined, involved a creative project worthy of the broad conceptions for which the United States is noted.

When the United States entered the war, it was evident

that the time was fast approaching when the reservoirs of raw material for the allies were to be found only in the United States and that America's effort should be so organized from the beginning as to furnish a continuous flow of this necessary raw material, not only for our own air program but for those of our Allies as well. It was clear, for instance, that the spruce, the fabric, the dope and the oil must be produced as a part of our program on a scale to supply also the air programs of our Allies. It was always the general Allied cause therefore which controlled the decisions in founding this industry, rather than the needs of the United States alone, and this is obviously the only correct point of view.

It is believed that the major decisions which had to be made by those in authority were accurately made, and promptly executed, and that as a consequence the record of the United States Air Service during the war shows a creditable performance. If America will but press on into the future, building upon the sound foundations now erected, she may lead the world in the development and utilization of aerial navigation for the triumphs of peace.

By a wise policy of readjustment, utilizing immediately our machines and our surplus aviators for the rapid expansion of the aerial mail and special passenger services, it will be possible to salvage for the nation a greater percentage of the money and energy invested for strictly war purposes than from any other feature of our war activities.

As a steward of the people, and in all humility therefore, I must not shrink from answering, as best I may, your request for a message which applies equally to peace and war.

The general principles which governed in the making of this enterprise in all of its ramifications of material and personnel, and to which the success attained must be attributed, may perhaps be formulated as follows:

VICTORY CREED

To foster individual talent, imagination and initiative, to couple with this a high degree of cooperation, and to subject these to a not too minute direction; the whole vitalized by a supreme purpose which serves as the magic key to unlock the upper strata of the energies of men.